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Monterey, California

Monthly and Seasonal Climatology over the
Global Tropics and Subtropics
for the Decade 1973 to 1983

Volume I. 200 mb winds

by

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This atlas of the 200 mb circulation field contains northern winter monthly and seasonal mean wind analyses, velocity potential and streamfunction from 40S to 60N over a global belt for the decade 1973 through 1983. In addition, the deviations of the individual annual seasonal and monthly means from their respective ten year means are presented for the same variables. The basic wind data used are the operational Global Band Analyses (GBA) of the United States Navy's Fleet Numerical Oceanography Center (FNOC). The analyses exhibit many interesting features, interannual variations and may shed some light on the understanding of the El Nino/Southern Oscillation phenomena.

ABSTRACT

This atlas of the 200 mb circulation field contains northern winter monthly and seasonal mean wind analyses, velocity potential and streamfunction from 40S to 60N over a global belt for the decade 1973 through 1983. In addition, the deviations of the individual annual seasonal and monthly means from their respective ten year means are presented for the same variables. The basic wind data used are the operational Global Band Analyses (GBA) of the United States Navy's Fleet Numerical Oceanography Center (FNOC). The analyses exhibit many interesting features, interannual variations and may shed some light on the understanding of the El Nino/Southern Oscillation phenomena.

1. INTRODUCTION

This atlas depicts the wintertime (December, January, February) seasonal and monthly mean atmospheric motion field at 200 mb for the decade 1973/1974 to 1982/1983. The charts display wind vectors, isotachs, velocity potential and streamfunction from 60N to 40S at 200 mb. In addition to the ten-year seasonal and monthly means and the individual annual seasonal and monthly averages, the deviations of the individual seasonal and monthly means from their ten-year averages are also presented. The seasonal calculations are based on the months of December, January, and February. To aid in depicting the onset of the winter monsoon circulations the monthly charts include the November as well as December, January, and February. The data used to derive these motion fields are the operational Global Band Analysis (GBA) of the United States Navy's Fleet Numerical Oceanography Center (FNOC). The procedures used in producing these analyses are described in section 2.

For reference seasonal and monthly means and deviations therefrom of the outgoing longwave radiation (OLR) as observed from the NOAA polar orbiting satellites for the period from 1974/1975 to 1982/1983 are available in volume II of this report.

The motion fields for the decade of winters from 1973/74 to 1982/83 are of interest since the data cover a period not hithertofor examined in other collections of data. Other works such as Oort (1983) and Krishnamurti et al. (1983) have presented detailed analyses of the decade prior to 1973. The 1973-1983 decade contains two El Nino/Southern Oscillation (ENSO) events, one occurring in 1976/77 and the other in 1982/83, the latter event is the most intense ENSO events yet observed. Also, the analyses presented here allow the FGGE winter to be placed in a longer term perspective since the FGGE/WMONEX experiment took place in the midst of the decade.

2. DATA SOURCES, ANALYSES AND COMPUTATIONS

2.1 GLOBAL BAND ANALYSIS

The wind data set used in this work are the operational analyses of the Global Band Analyses (GBA) of FNOC. These data are produced four times daily by objective procedures on a mercator grid which extends from 60N to 40S. The use of the mercator secant projection results in a change in the actual distance between grid points from 140 km at 60N to a maximum value of 280 km at the equator. The objective scheme is designed to take advantage of all the reports in the operational data base, surface synoptic, aircraft, pilot balloons, rawindsonde and satellite data.

The analysis is performed every six hours for the surface, 700, 400, 250 and 200 mb levels. The first guess field used as input for the objective analysis is the six-hour persistence field. The operational approach is to first interpolate the irregularly spaced data to grid points using a successive corrections technique based on Cressman's (1959) method. The successive corrections method takes several scans through the data reducing the scan radius on each successive scan. Analyses are performed of both wind and temperature by this method. These fields are then adjusted by a set of numerical variational analysis (NVA) equations which have incorporated the dynamical constraints of the momentum equations with friction included in the surface layer (Lewis and Grayson, 1972). Temperature and wind fields are adjusted subject to mutual constraints on the fields. However, the 200 mb wind data used in this atlas serve only as a boundary condition for NVA and are not subject to the adjustment.

2.2 COMPUTATION OF STREAMFUNCTION AND VELOCITY POTENTIAL

The streamfunction (ψ) and velocity potential (χ) were computed from the following equations:

$$\nabla^2\psi = \zeta \qquad (1)$$

$$\nabla^2\chi = \delta \qquad (2)$$

where:

ζ is the relative vorticity = $\partial v/\partial y - \partial u/\partial x$

and

δ is the divergence = $\partial u/\partial x + \partial v/\partial y$.

Both ζ and δ were computed using centered differences on the GBA mercator grid.

Equation 2 was solved using the boundary condition that $\chi = 0$ at the north and south boundaries which are 60N and 40S respectively. The method used to compute ψ was essentially method II of Shukla and Saha (1974). This technique uses the previously computed values of χ to formulate boundary conditions for ψ. The values of ψ above 50N are not displayed because of obvious difficulties that the solution for ψ encountered on this boundary. It was felt that displaying these results detracted from the overall presentation. Although the boundary condition described here produced the best results of the many different methods tried, the location of the boundary in the meteorologically active region at 60N proved to be troublesome. The depiction of the divergence field appears reasonable away from the boundary. Comparison with the global fields produced by the National Meteorological Center (NMC) for the years since the NMC global product has become available indicate that the effect of the boundary condition on χ is not significant between 40N and 30S. Thus the ψ and χ fields in the equatorial regions are sufficiently removed from the boundaries that we can assume that these values are not unduly affected by the choice of boundary conditions.

3. DISCUSSION

3.1 INTRODUCTION

This discussion is not intended to be a comprehensive review of the tremendous amount of data contained in the accompanying figures. Rather the intent is to describe in general terms some of the more obvious general features of interest.

3.2 EL NINO/SOUTHERN OSCILLATION EVENTS

A perusal of the charts of the seasonal means of 200 mb χ clearly show that the dominant center of interannual variability is located in the central Pacific. These fluctuations can be associated with changes driven by the Southern Oscillation.

There are a great many studies in the literature about the global scale aspects of the ENSO events. The particular collection of charts presented here depicts the wintertime 200 mb motion fields for two such events occurring in 1976/77 and 1982/83. Liebmann and Hartmann (1982) describe the anomalous (based on a three year average) patterns of OLR for the 1976/77 event. They show the increase in convection activity over Indonesia shifts eastward after the sea-surface temperature (SST) in the east Pacific becomes anomalously warm. The South Pacific convergence zone (SPCZ) intensifies and moves eastward but does not reach its maximum intensity until more than a year after the SST increases occur. Lau et al. (1983) consider the anomalous OLR, ψ and χ patterns for both the 76/77 and 82/83 ENSO events using the same data as presented here (OLR data is presented in volume II). They concluded that the circulation changes associated with each individual ENSO event can be quite different, but that the anomalous OLR patterns and circulation

features within each event were consistent. They showed that prior to the ENSO of 1976/77 the equatorial central Pacific convection was strongly suppressed for at least a two year period prior to December 1975. The seasonal data of 1976/77 and 1977/78 evince a dramatic reversal in the χ pattern in the eastern Pacific.

3.3 DECADE OVERVIEW

If one examines the seasonal means of χ and OLR it becomes apparent that there is a shift in the equatorial Pacific about the middle of the decade. Figure I is a time series of the deviations from the ten-year mean of the winter season χ field averaged over the region from 175E to 140W and 10N to 10S. This region, located in the mid-Pacific, is one of large inter-seasonal variability. The figure indicates two regimes, one going from 1973/75 to 1976/77, the other from 1977/78 to 1982/83. The former has relatively low values of χ, the latter relatively high values. This can be interpreted as an increase in the upper-level divergence in this region in the latter part of the decade. Figure I also contains a time series of the deviations from the nine-year mean of the winter season OLR (winter 1973/74 not available) averaged over the same region as the χ values. Negative values indicate relatively decreased OLR which can be construed to mean decreased convection in the tropics. Figure I demonstrates a strong negative correlation, which implies that the independently derived data sets are consistent on the seasonal time scale. Note that the OLR values are plotted on an inverse scale from the χ graph. This also indicates that the FGGE winter (1978/79) is more characteristic of the regime in the latter half of the decade and care must be taken extrapolating inferences drawn from the FGGE data to other years.

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FIGURES

Figure I

Time series of the deviations of the seasonal means of χ and OLR from their respective ten- and nine- year seasonal means. The values are areal averages over the region bounded by 10N to 10S and 175E to 140W. The χ values are represented by the solid line, the OLR values by the dashed line. Note that the OLR ordinate scale (on the left hand side of the graph) is reversed from that of the χ ordinate. The ten-year mean value of χ for the region is $4.6 \times 10^{-6} m^{-1} s^{-2}$. The nine-year mean of OLR for the region is 234 Wm^2.

Figures A1 - A3

Ten winter season (1973/74 - 1982/83) mean circulation fields at 200 mb. Variables displayed are streamfunction, velocity potential, wind vectors and isotachs. Contour interval for the streamfunction is $1.0 \times 10^7 m^2 s^{-1}$, for velocity potential it is $1.0 \times 10^6 m^6 s^{-1}$, and for isotachs it is 10 ms^{-1}. The vector scale is given in the upper right portion of the wind vector isotach plots. The grid intervals of the FNOC Global Band Analysis mercator grid are shown on the left hand side and bottom of each figure. The longitude grid is marked every 30° from the Greenwich meridian on the extreme left and the latitude is marked every 10° from 40S at the bottom of the figure.

Figures B1 - B30

Individual winter season mean and deviation circulation fields at 200 mb, for the winters from 1973/74 to 1982/83. The deviations are differences from the ten year seasonal mean (Figs. A1 and A3). The figures are marked with the year corresponding to the year of the January and February of the winter. Variables displayed are the streamfunction, velocity potential, wind vectors and isotachs. For the mean fields the contour interval for the streamfunction is 1.0 x $10^7 m^2 s^{-1}$, for velocity potential it is 1.0 x $10^6 m^2 s^{-1}$, and for isotachs it is 20 ms^{-1}. For the deviation fields the contour interval for the streamfunction is 2.0 x $10^6 m^2 s^{-1}$, for velocity potential it is 1.0 x $10^6 m^2 s^{-1}$, and for isotachs it is 10 ms^{-1}. On the deviation plots contours with negative values are dashed, those with positive values and the zero line are solid. The vector scale is given in the upper right portion of the wind vector isotach plots.

Figure C1 - C12

Ten-year (1973 - 1983) monthly mean circulation fields at 200 mb. The months displayed are November, December, January,and February. Variables displayed are streamfunction, velocity potential, wind vectors and isotachs. Contour interval for the streamfunction is 1.0 x $10^7 m^2 s^{-1}$, for velocity potential it is 1.0 x $10^6 m^2 s^{-1}$, and for isotachs it is 20 ms^{-1}. The vector scale is given in the upper right portion of the wind vector isotach plots.

Figures D1 - D120

Individual monthly mean and deviation circulation fields at 200 mb, for the months from November 1973 to February 1983. The deviations are differences from the ten-year monthly means (Figs. C1 and C12). The months displayed are November, December, January, and February. Variables displayed are the streamfunction, velocity potential, wind vectors and isotachs. For the mean fields the contour interval for the streamfunction is $1.0 \times 10^7 m^2 s^{-1}$, for velocity potential it is $1.0 \times 10^6 m^2 s^{-1}$, and for isotachs it is $20\ ms^{-1}$. For the deviation fields the contour interval for the streamfunction is $1.0 \times 10^7 m^2 s^{-1}$, for velocity potential it is $1.0 \times 10^6 m^2 s^{-1}$, and for isotachs it is $5\ ms^{-1}$. On the deviation plots contours with negative values are dashed, those with positive values and the zero line are solid. The vector scale is given in the upper right portion of the wind vector isotach plots.

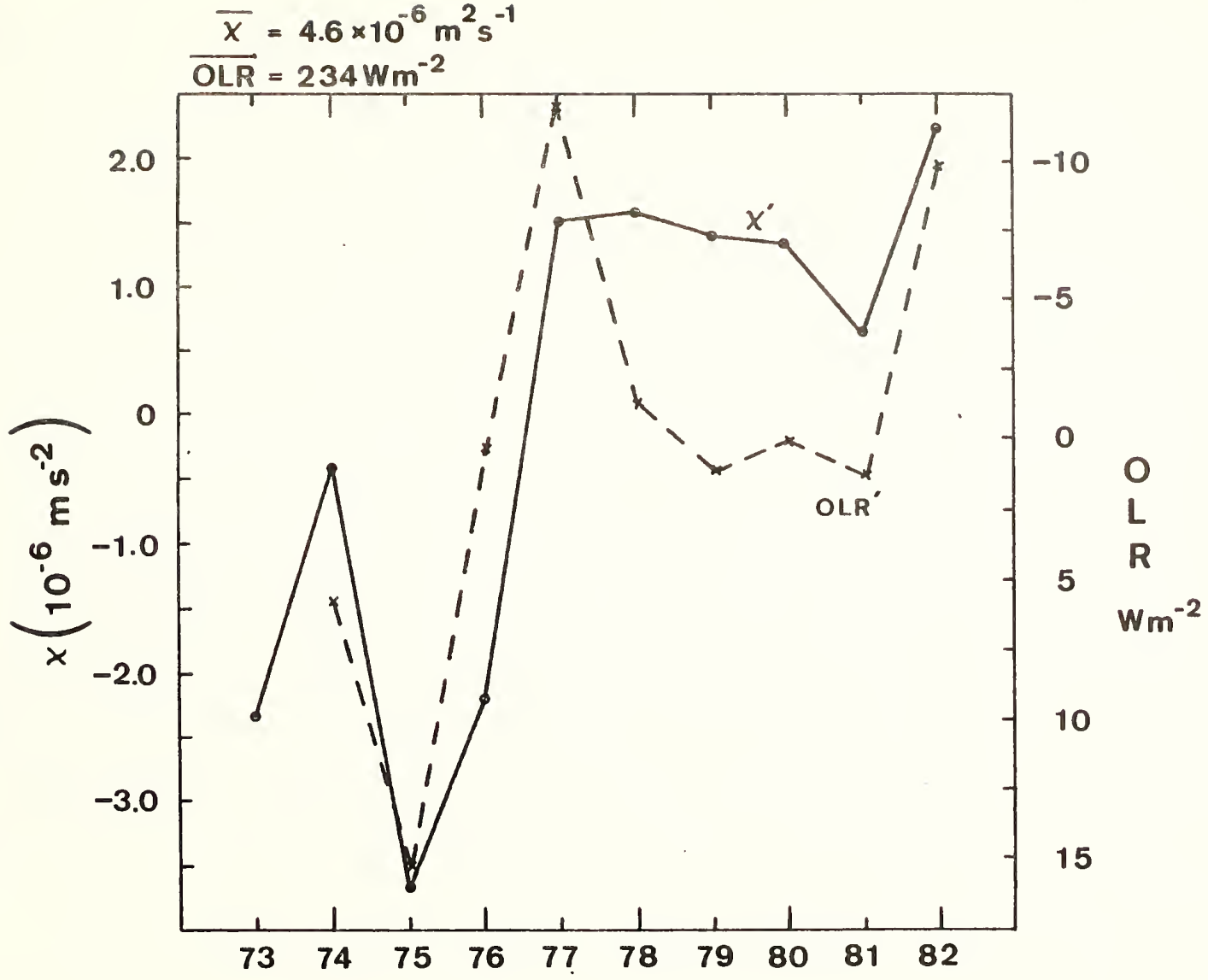
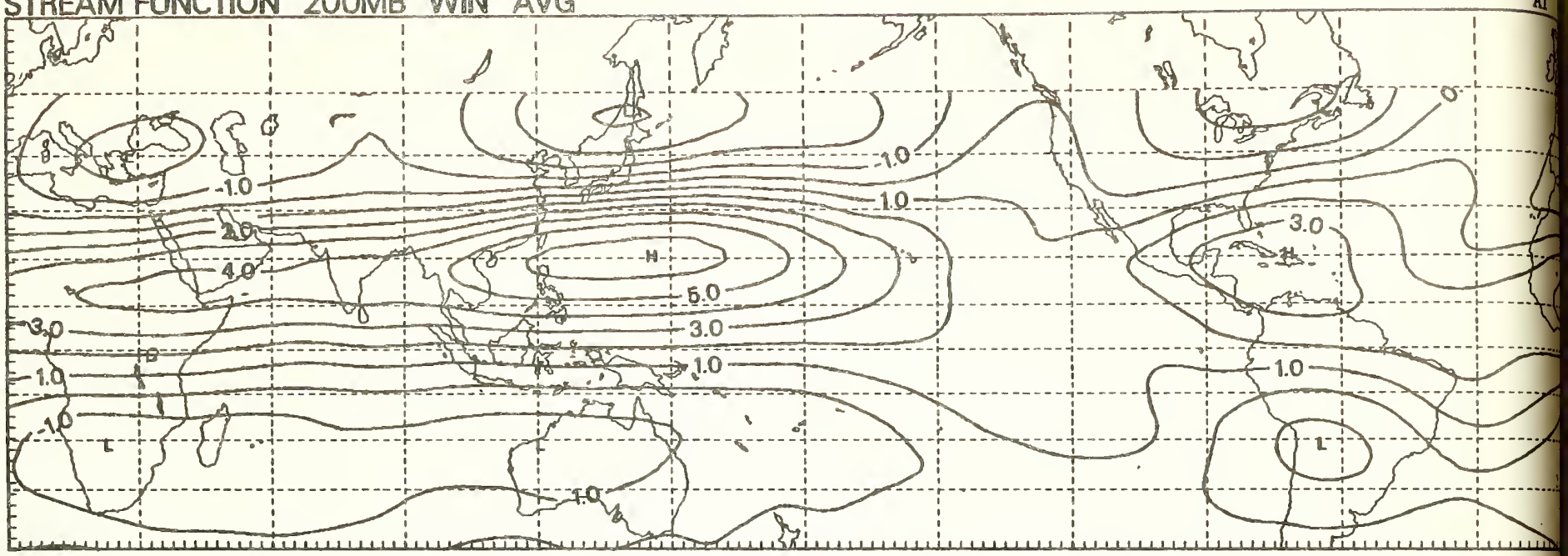

$\overline{\chi}$ = 4.6 ×10^{-6} m^{2}s^{-1}
$\overline{OLR}$ = 234 Wm^{-2}
2.0
1.0
0
-1.0
-2.0
-3.0
χ (10^{-6} ms^{-2})
-10
-5
0
5
10
15
OLR Wm^{-2}
χ′
OLR′
73
74
75
76
77
78
79
80
81
82

Figure I

STREAM FUNCTION 200MB WIN AVG

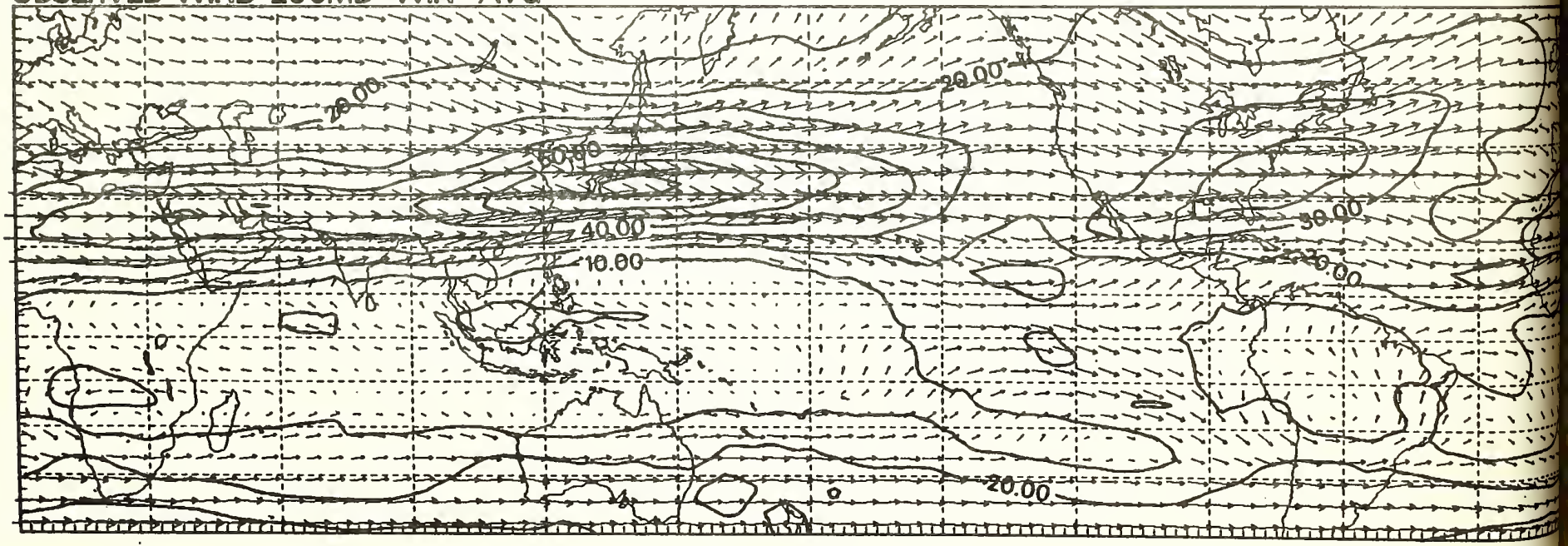
A1



OBSERVED WIND 200MB WIN AVG

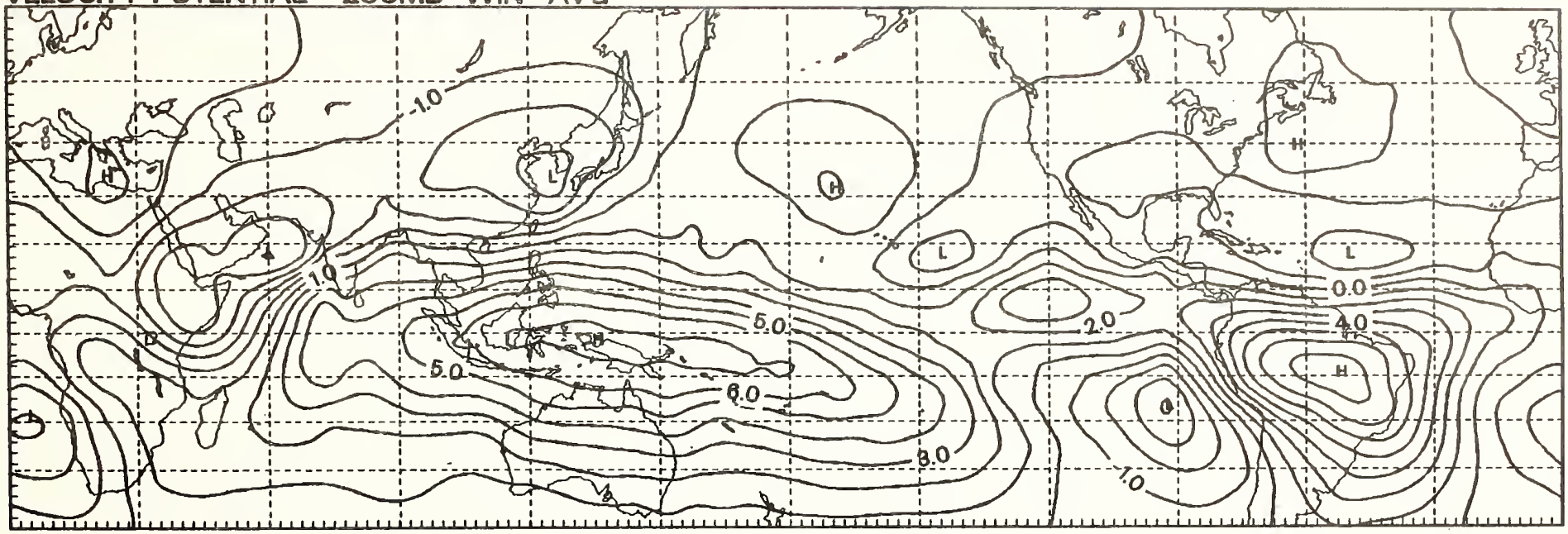
SCALE = 20

A2



VELOCITY POTENTIAL 200MB WIN AVG

A3



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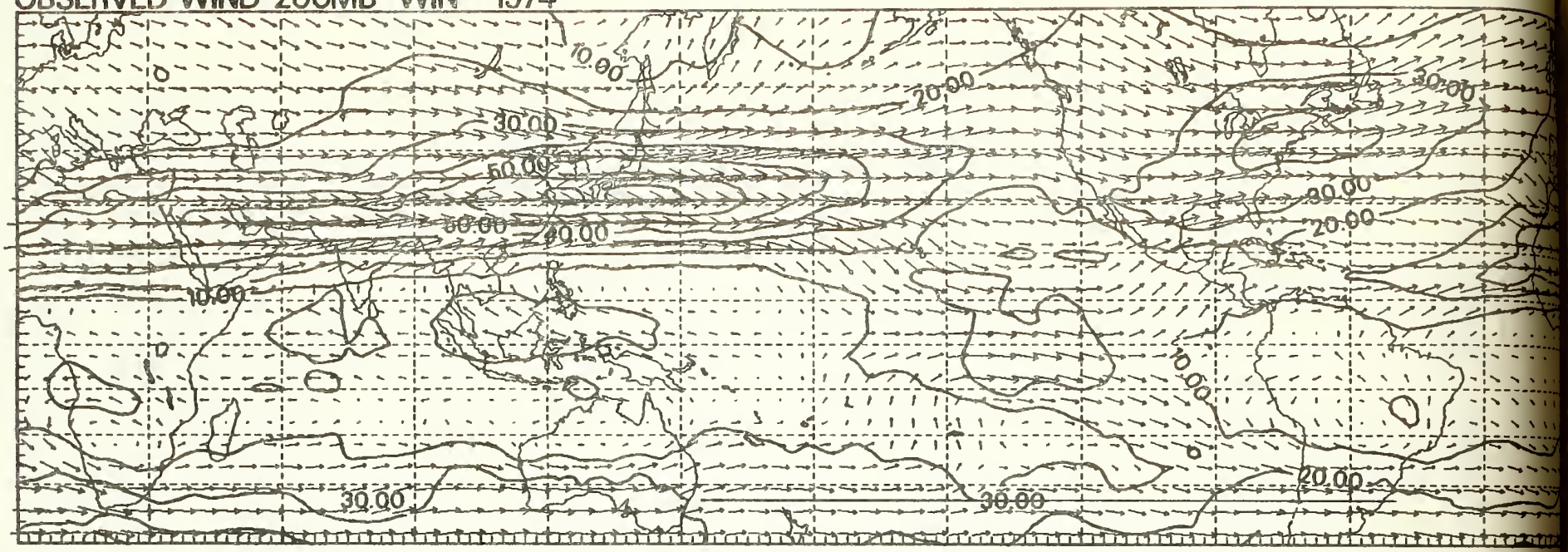

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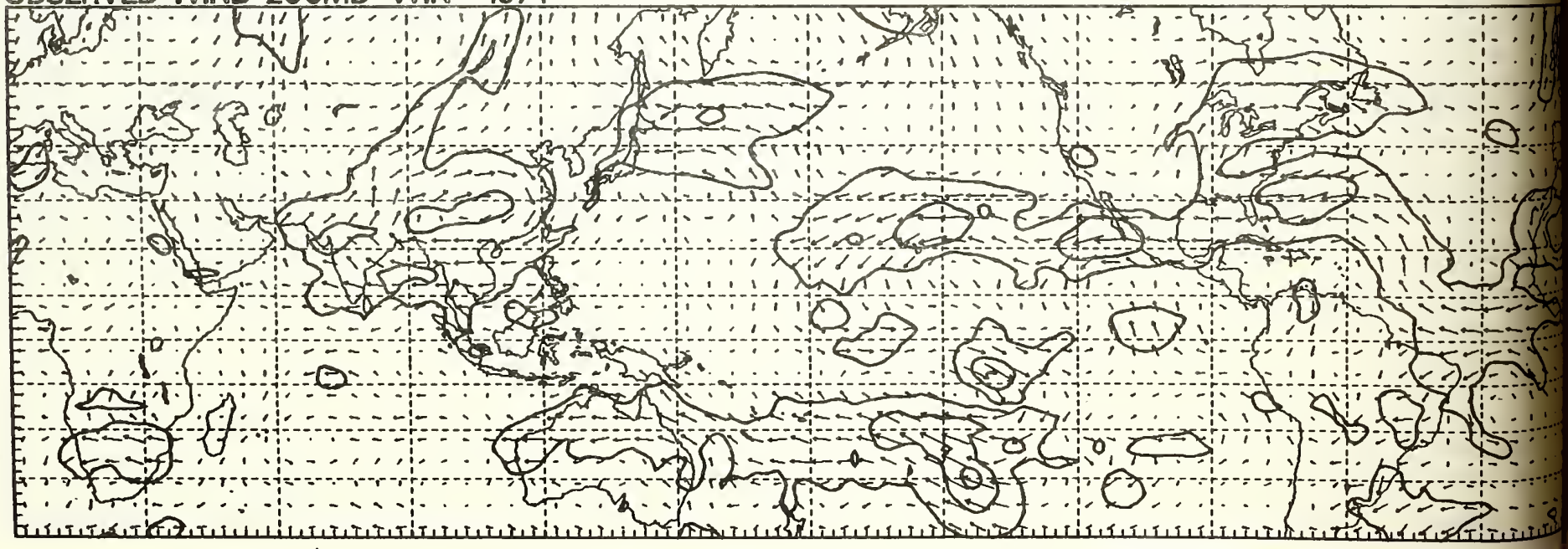

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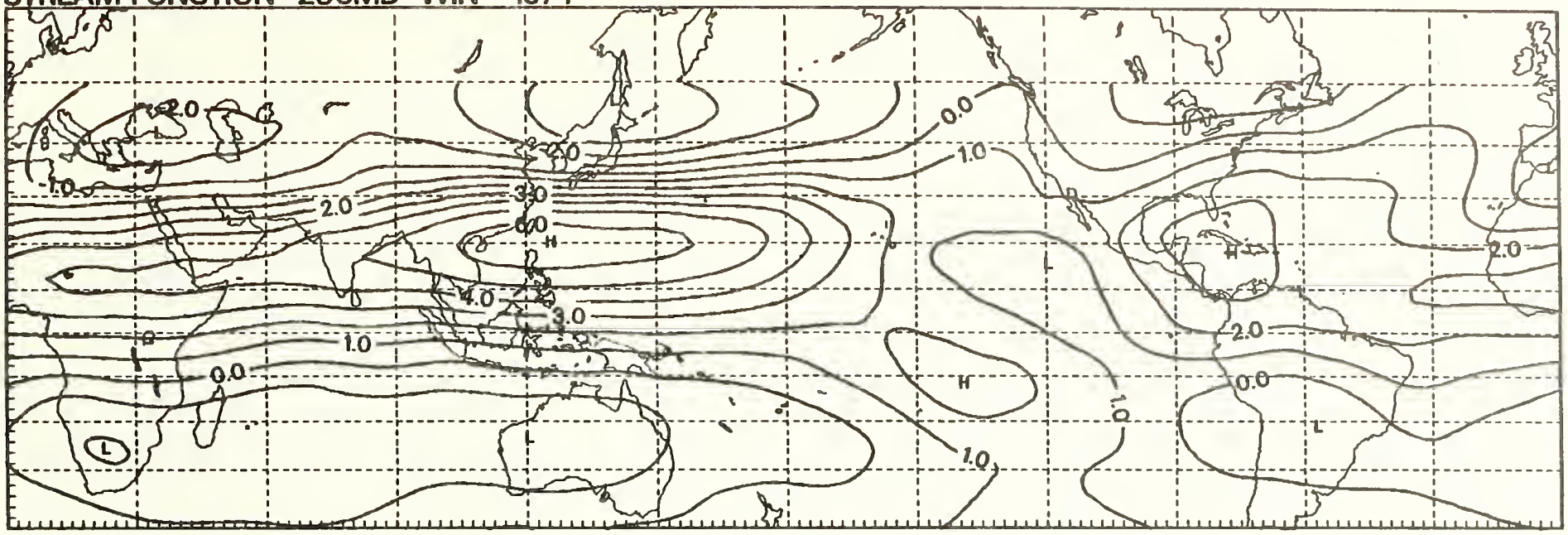

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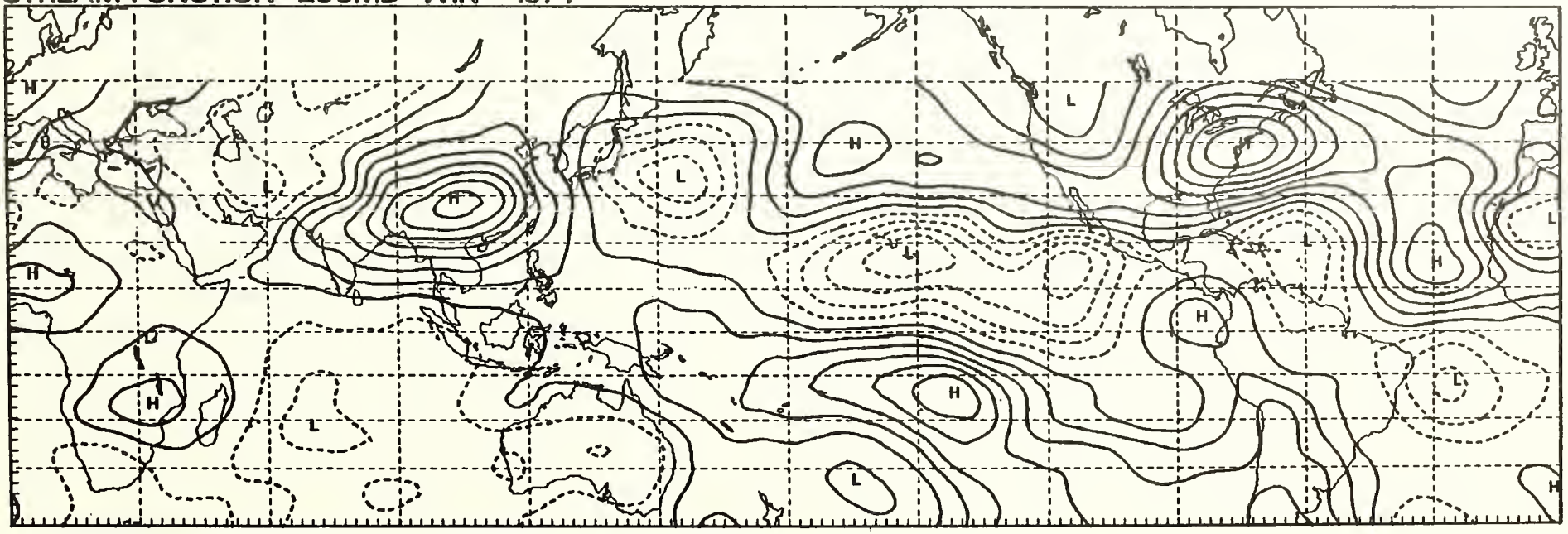

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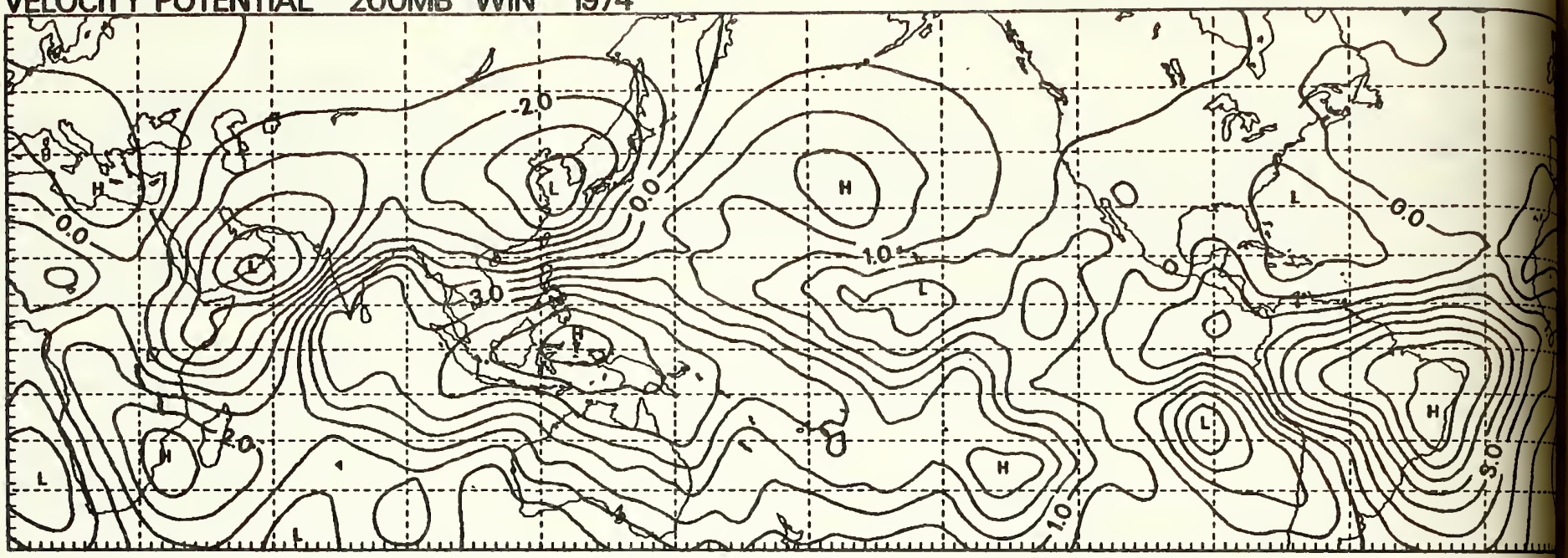

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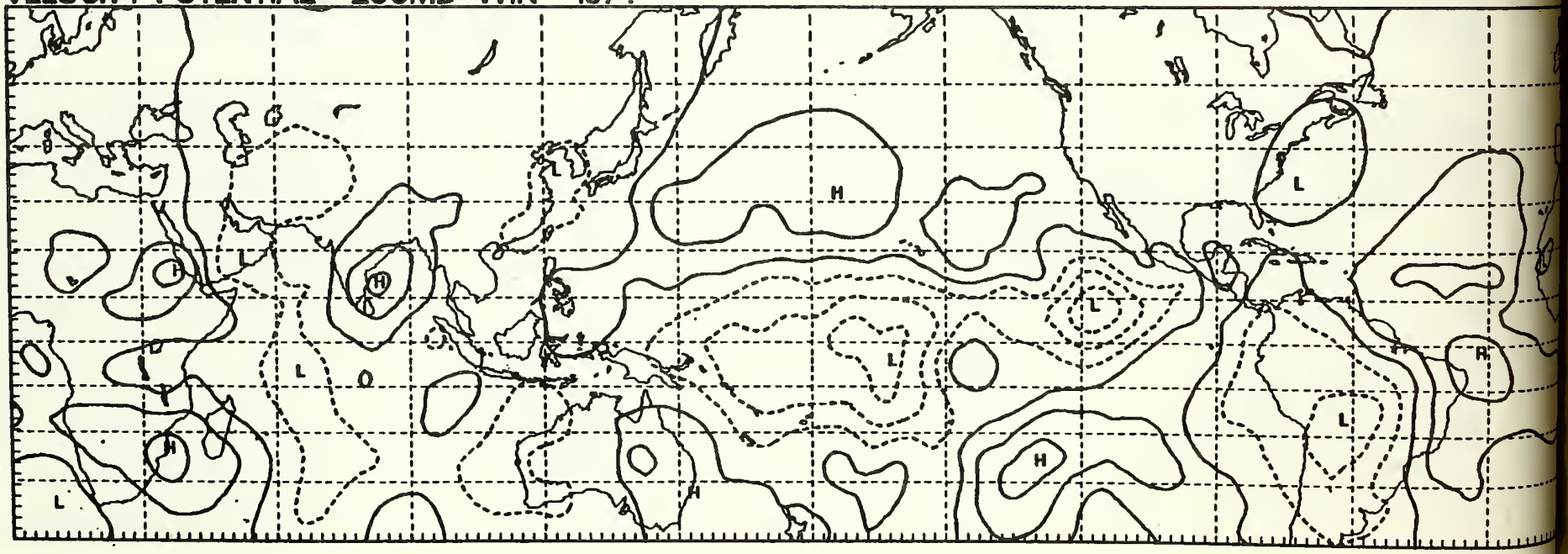

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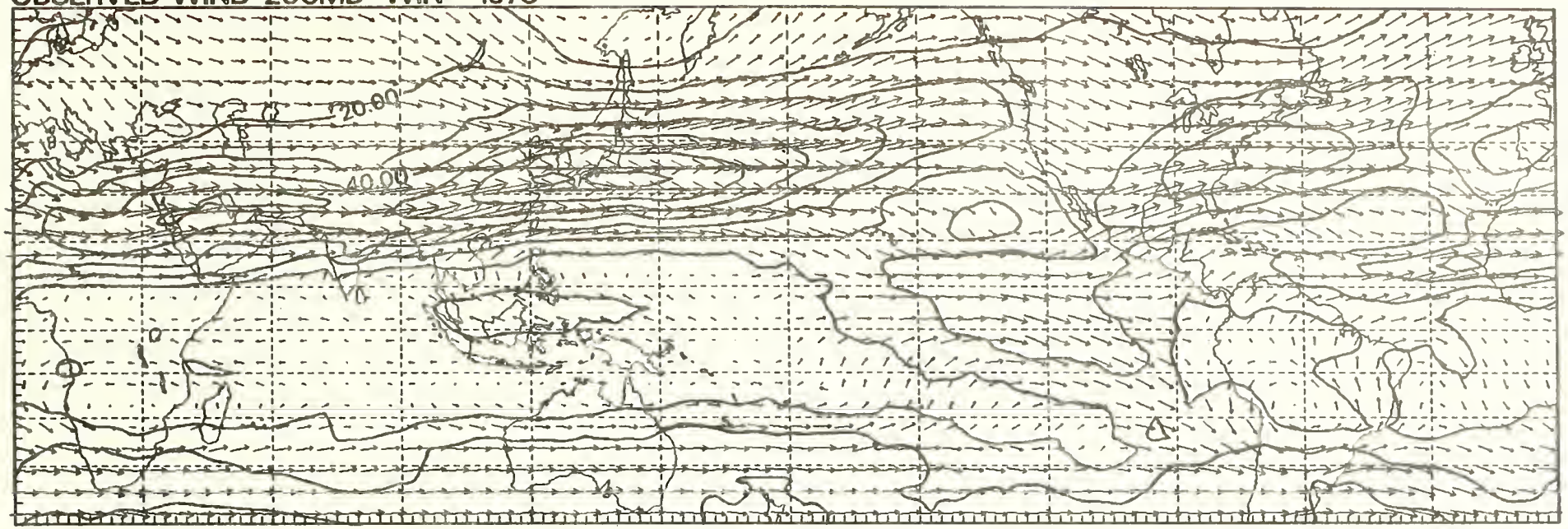

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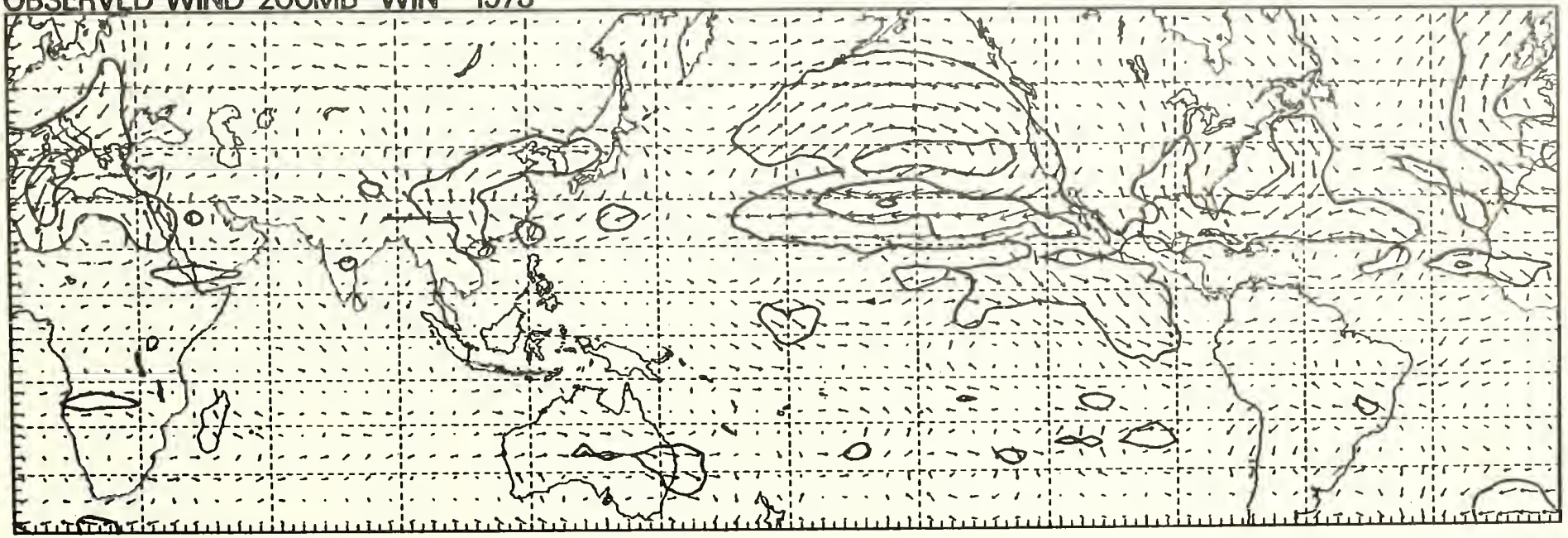

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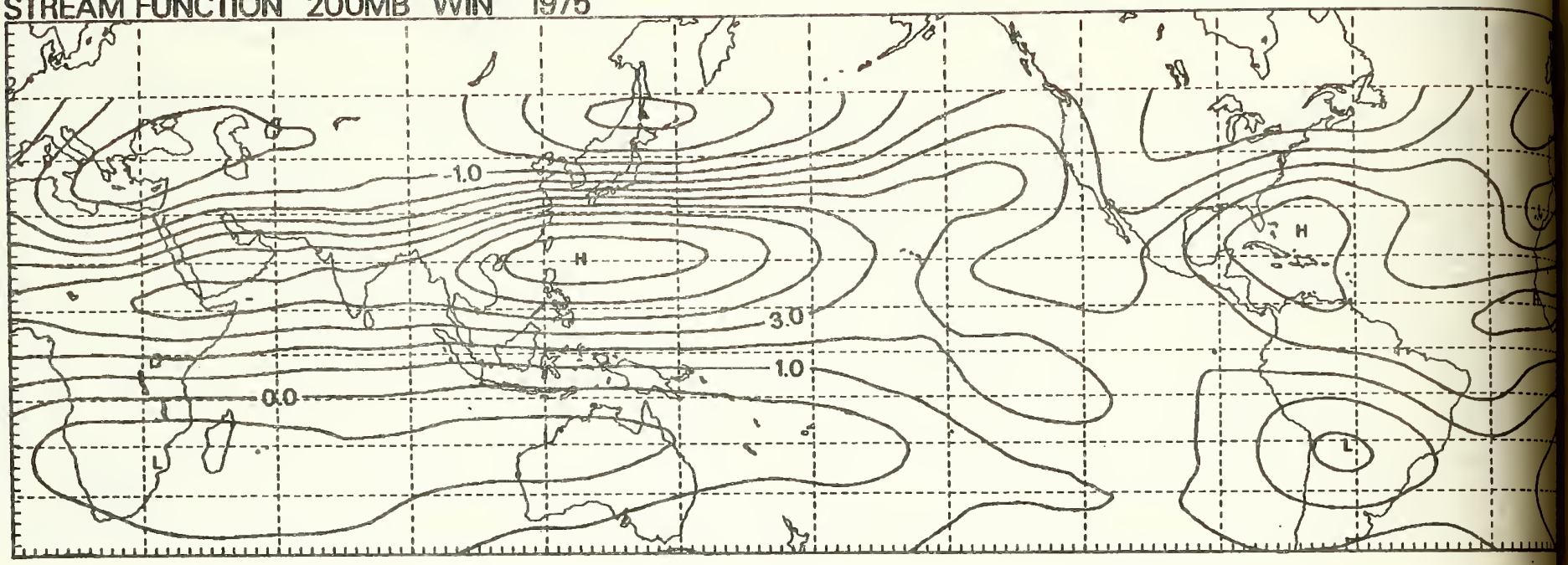

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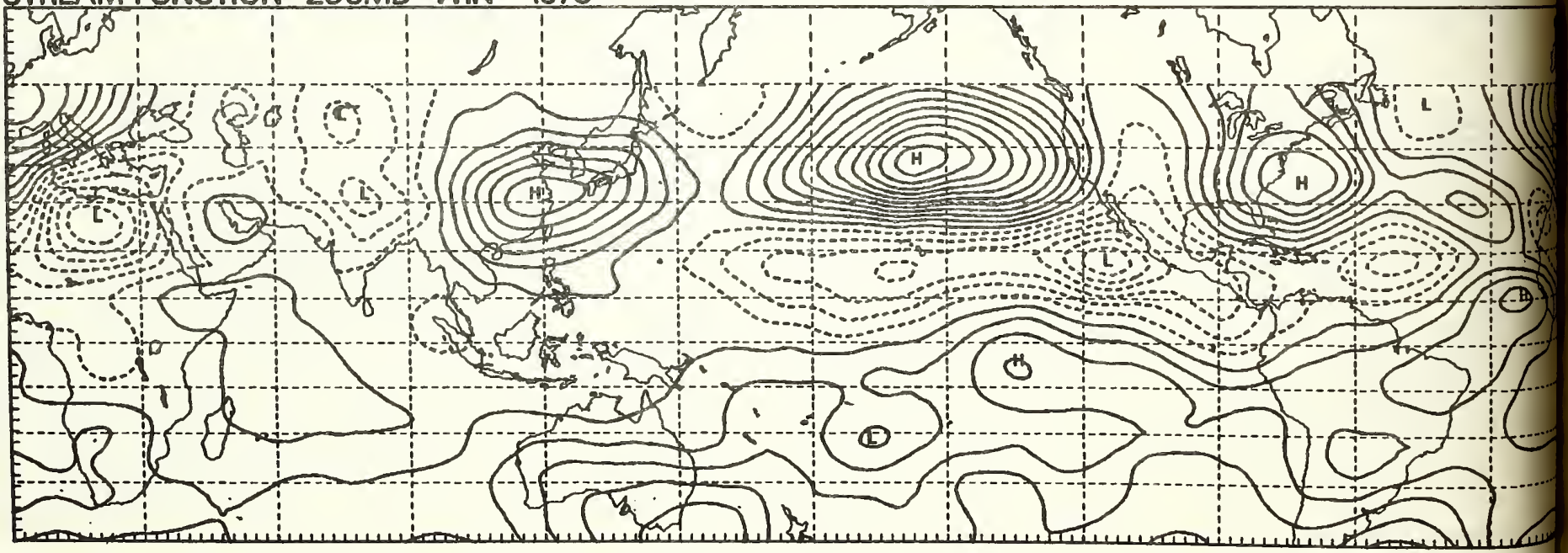

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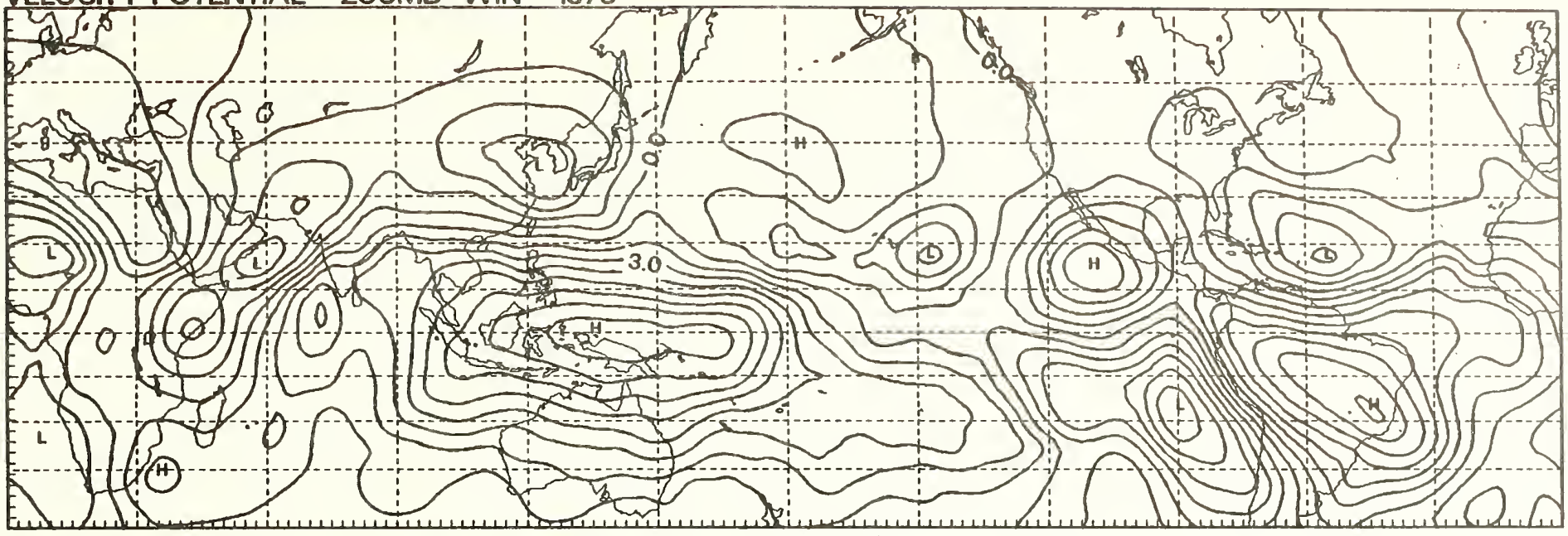

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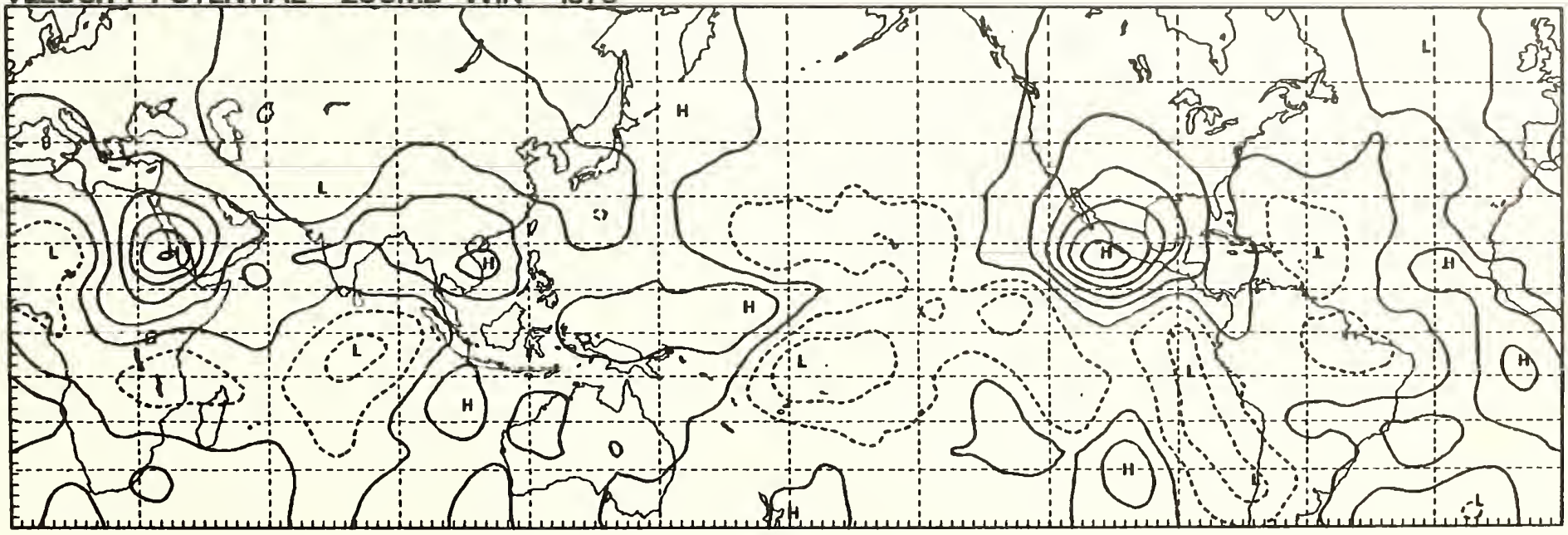

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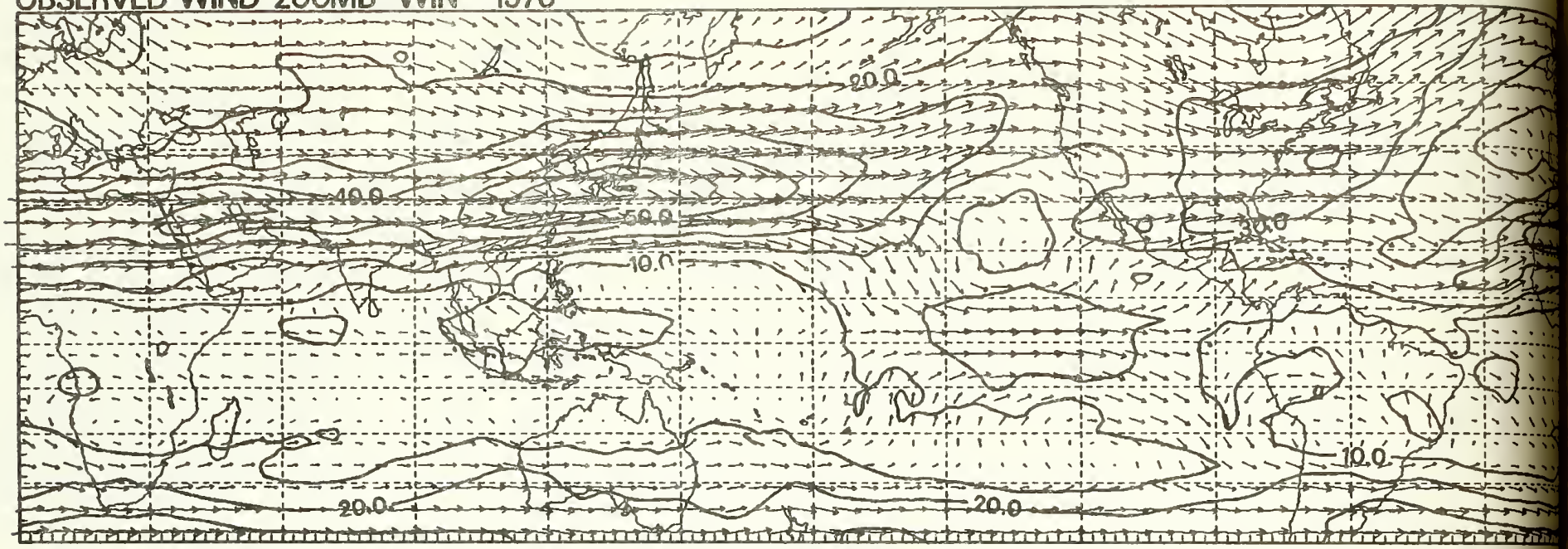

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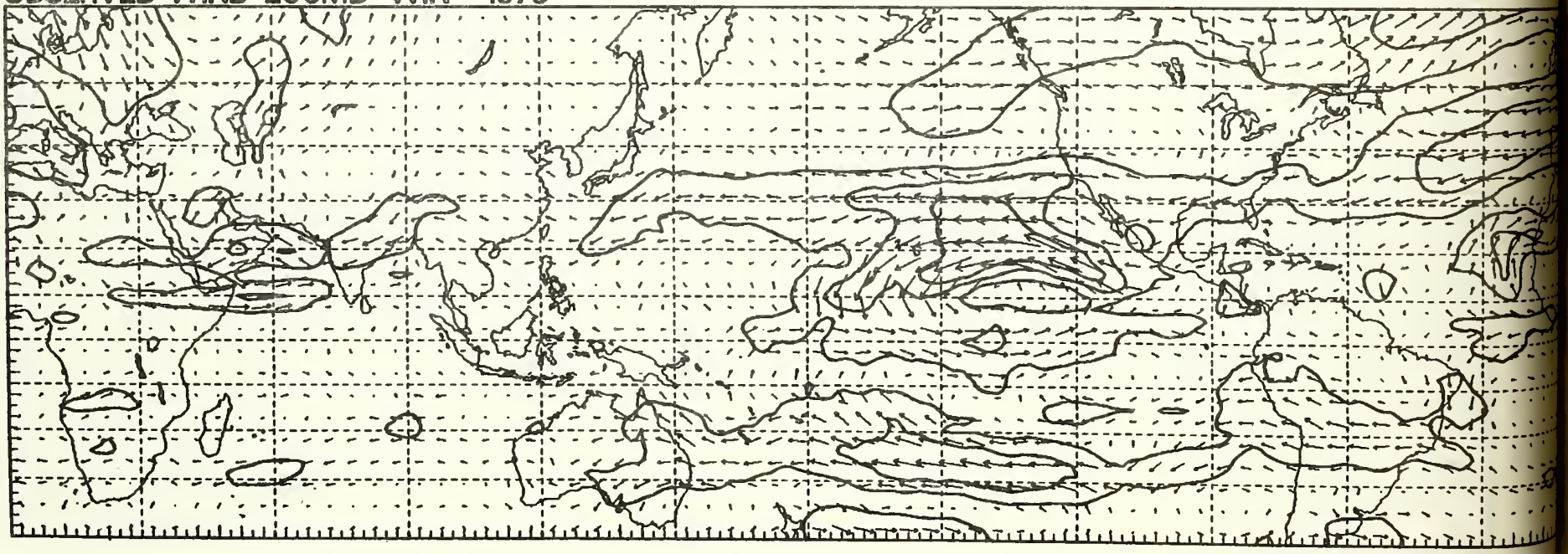

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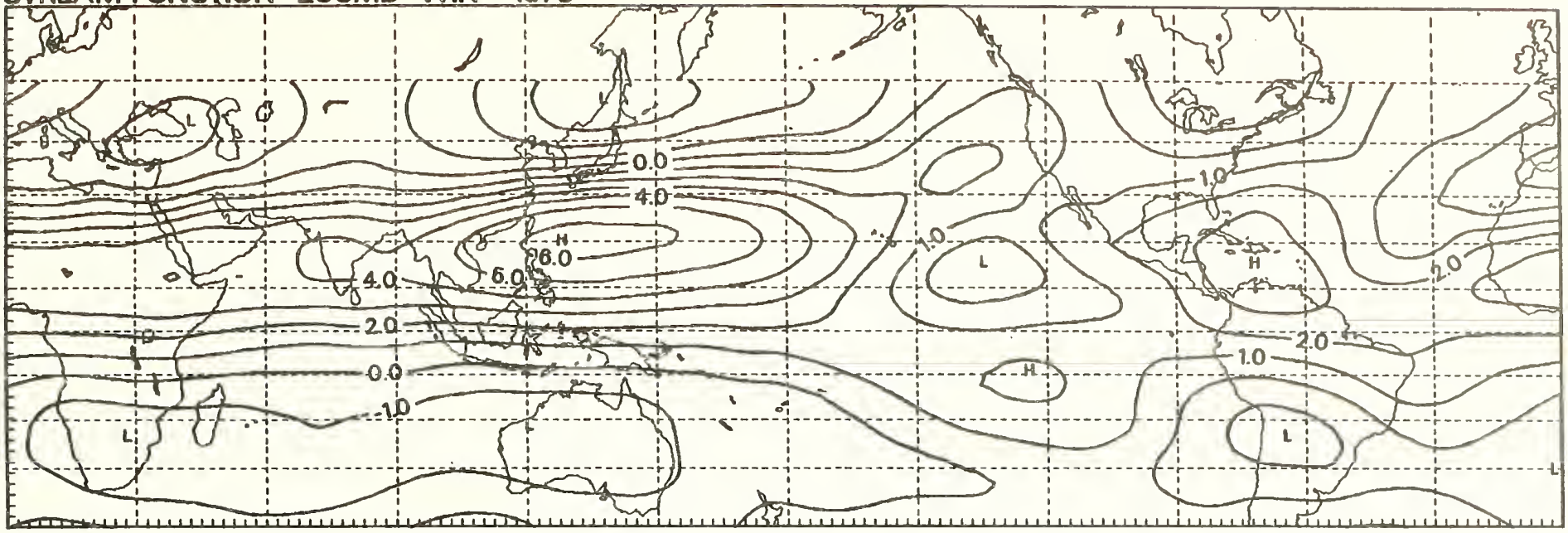

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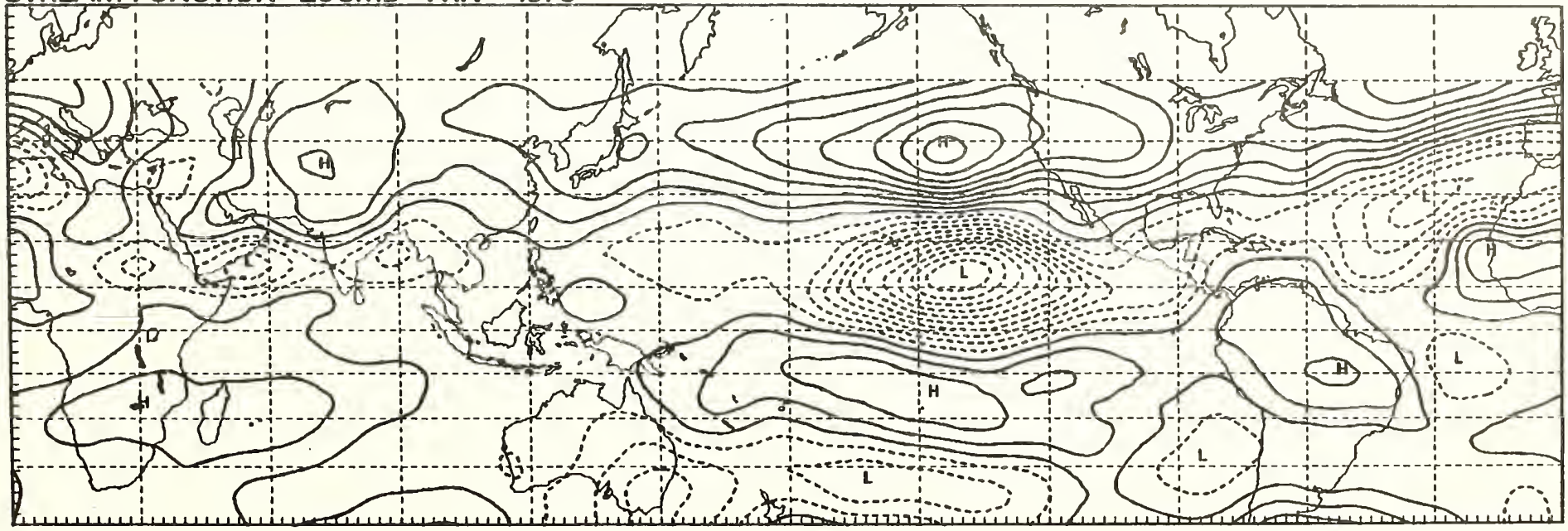

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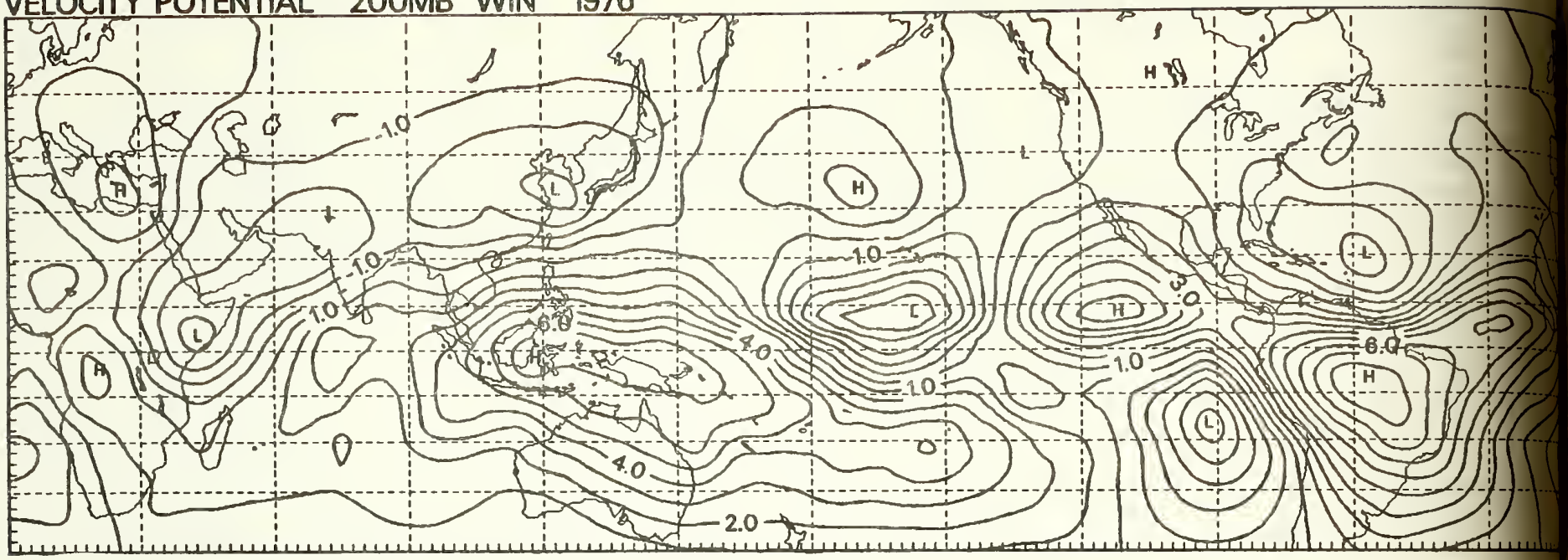

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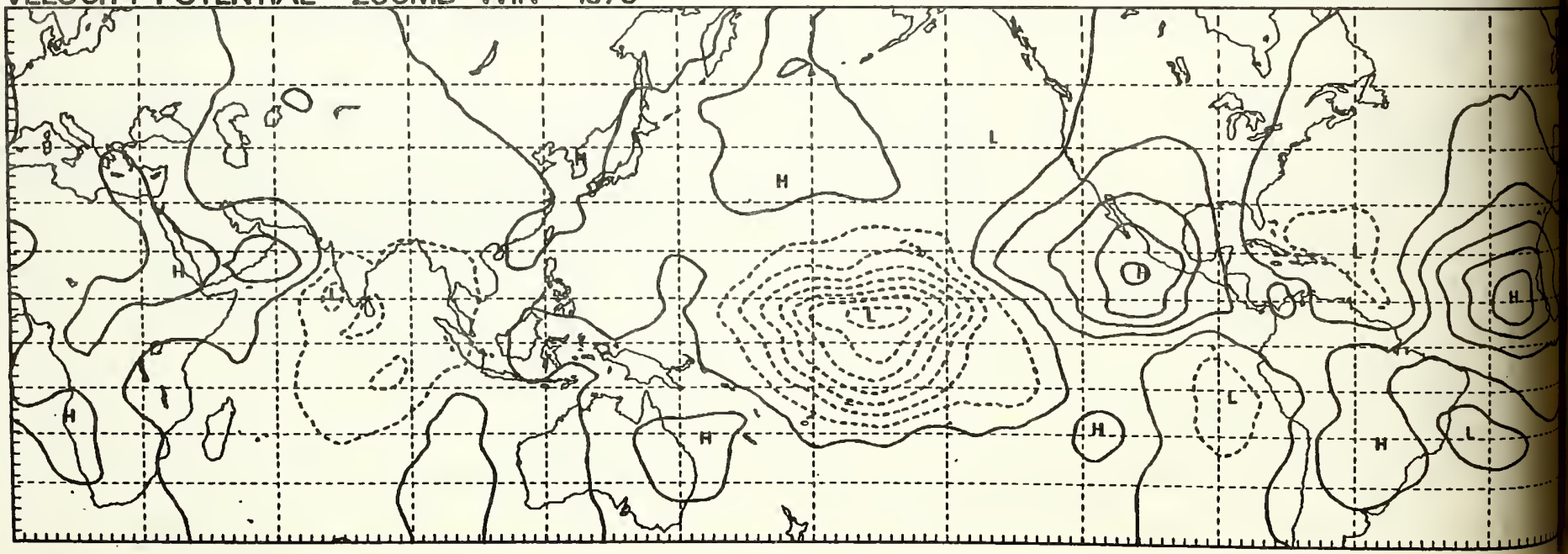

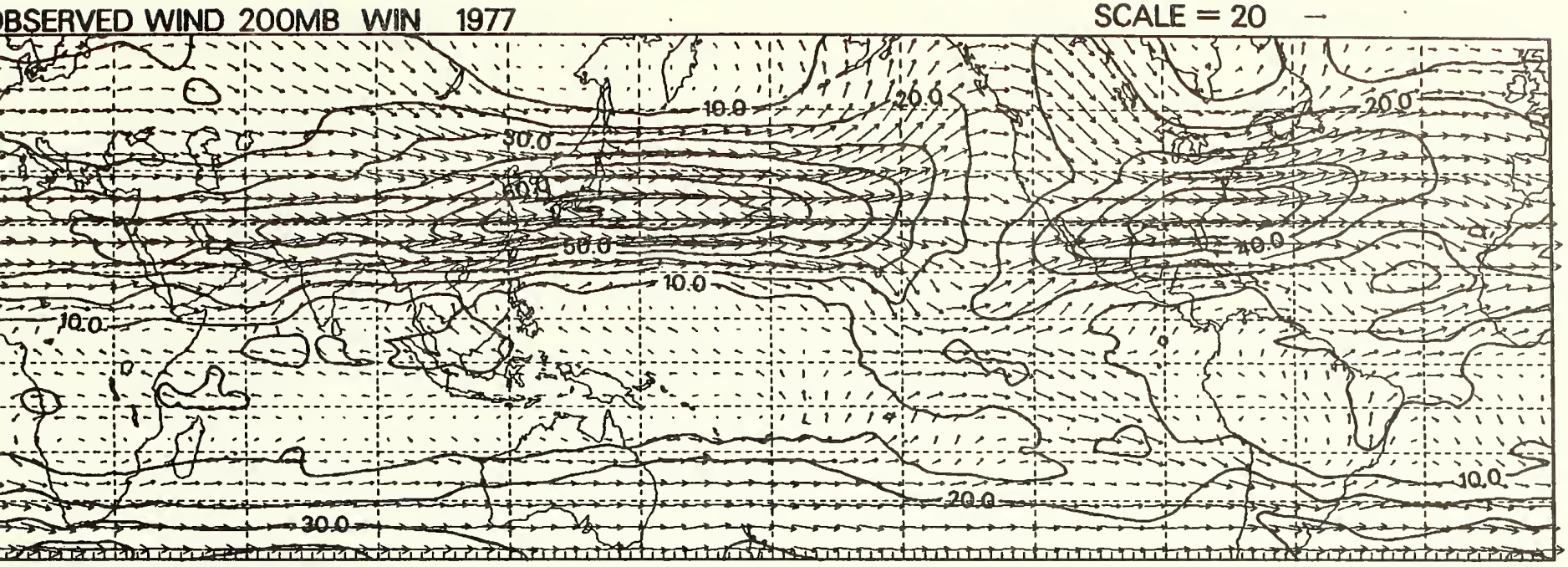
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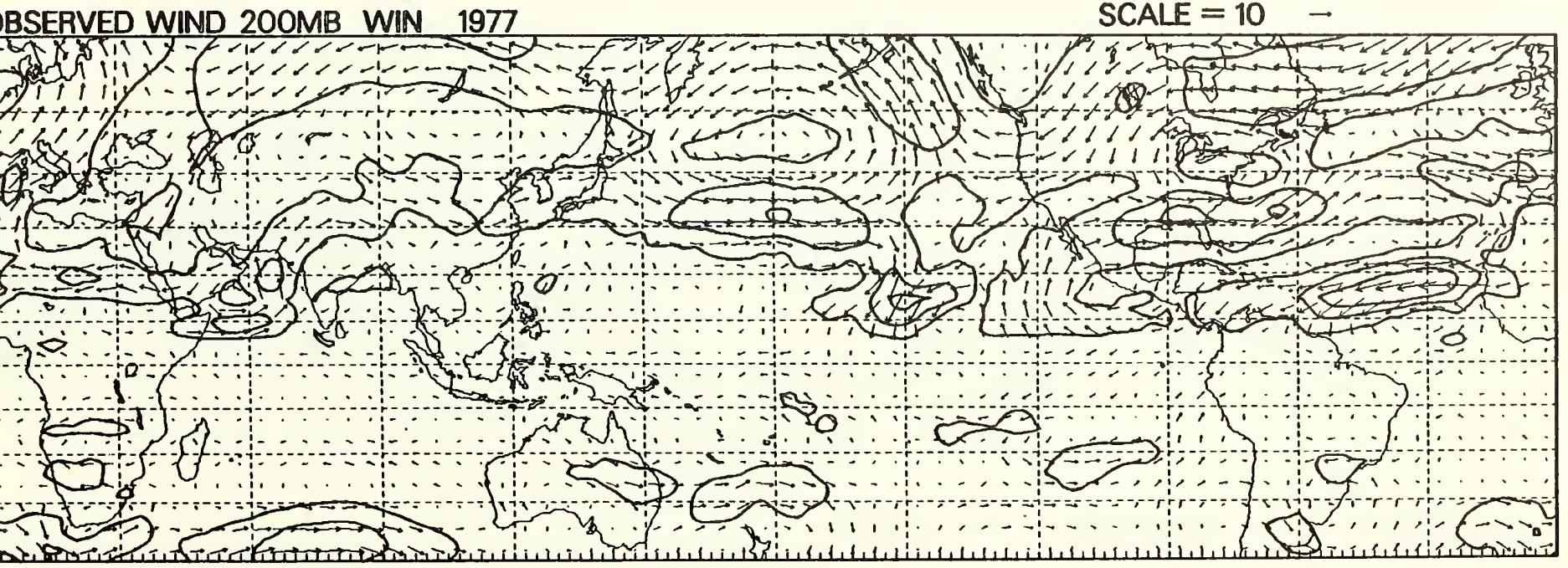
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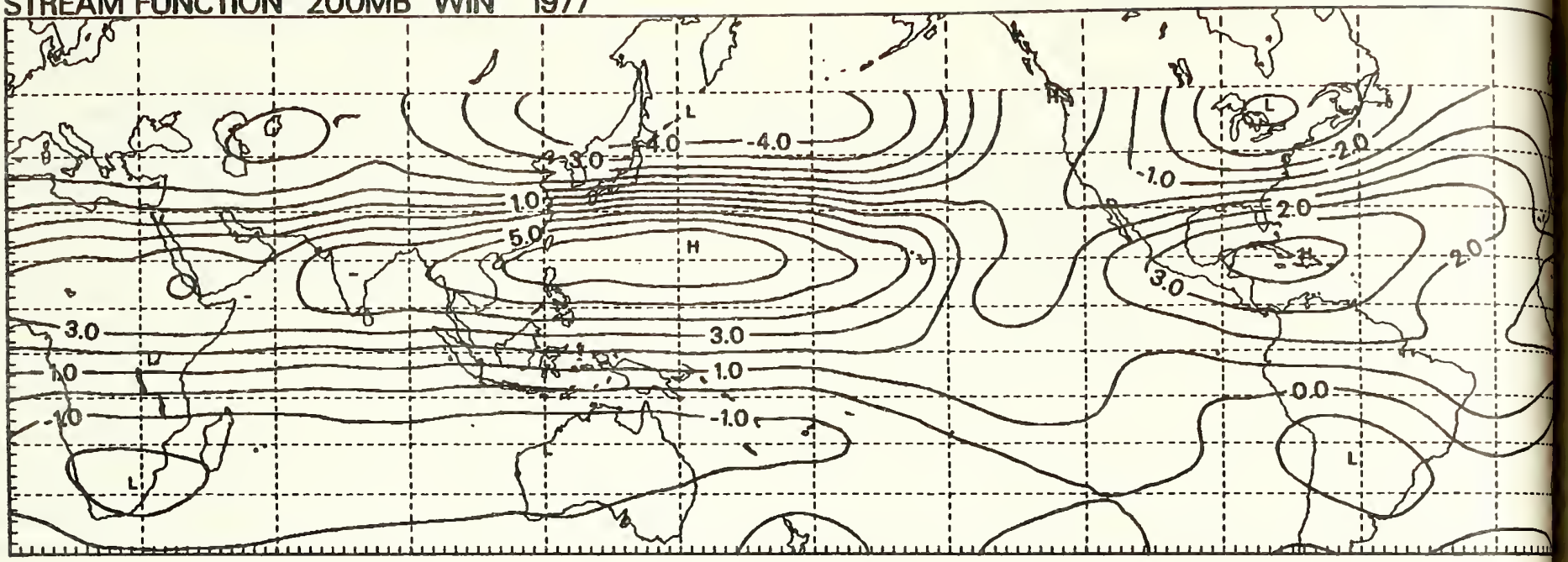
STREAM FUNCTION 200MB WIN 1977



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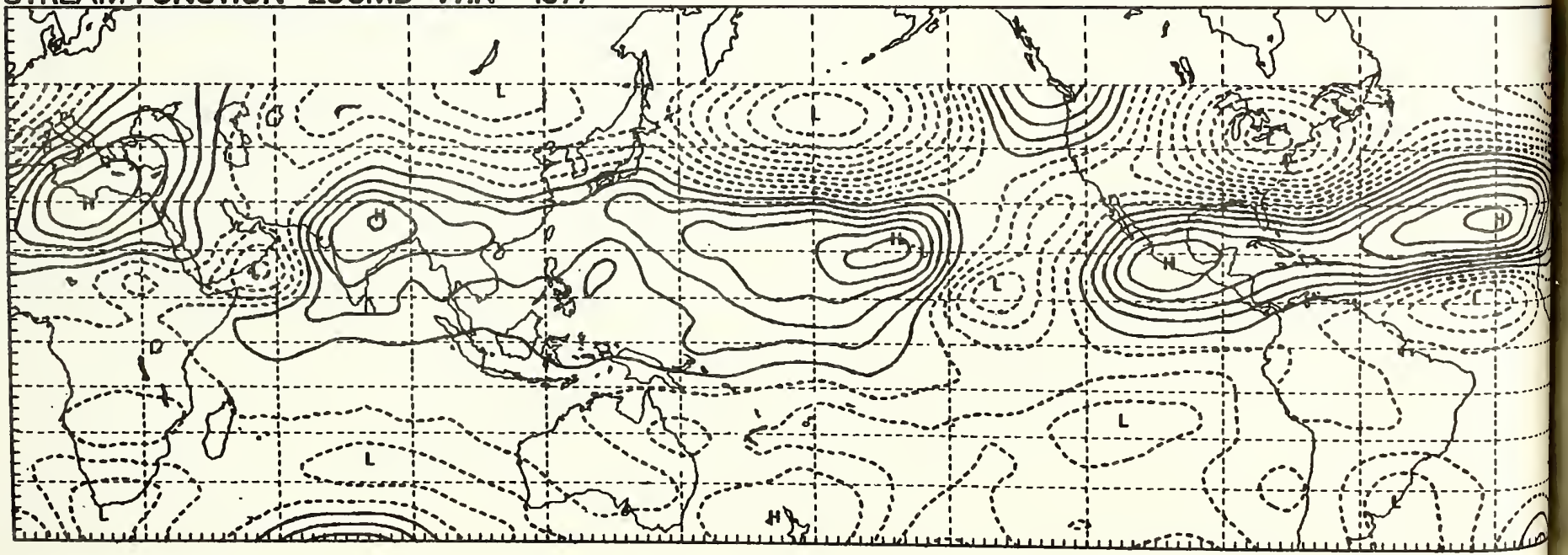

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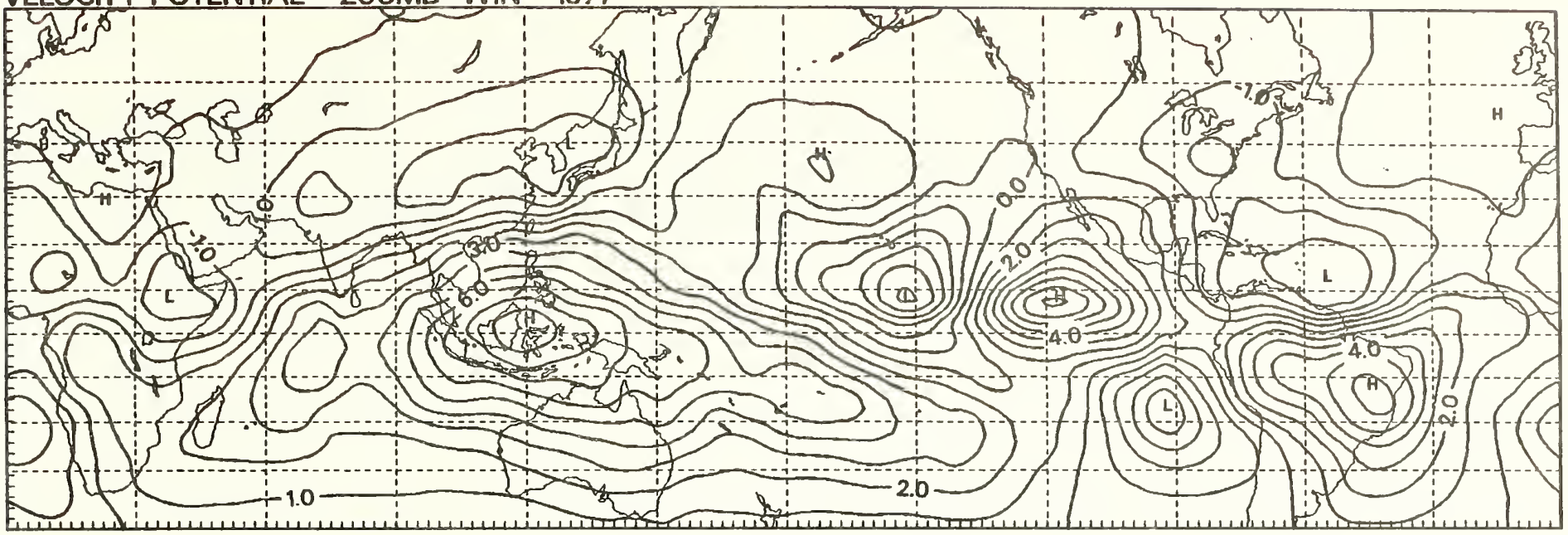

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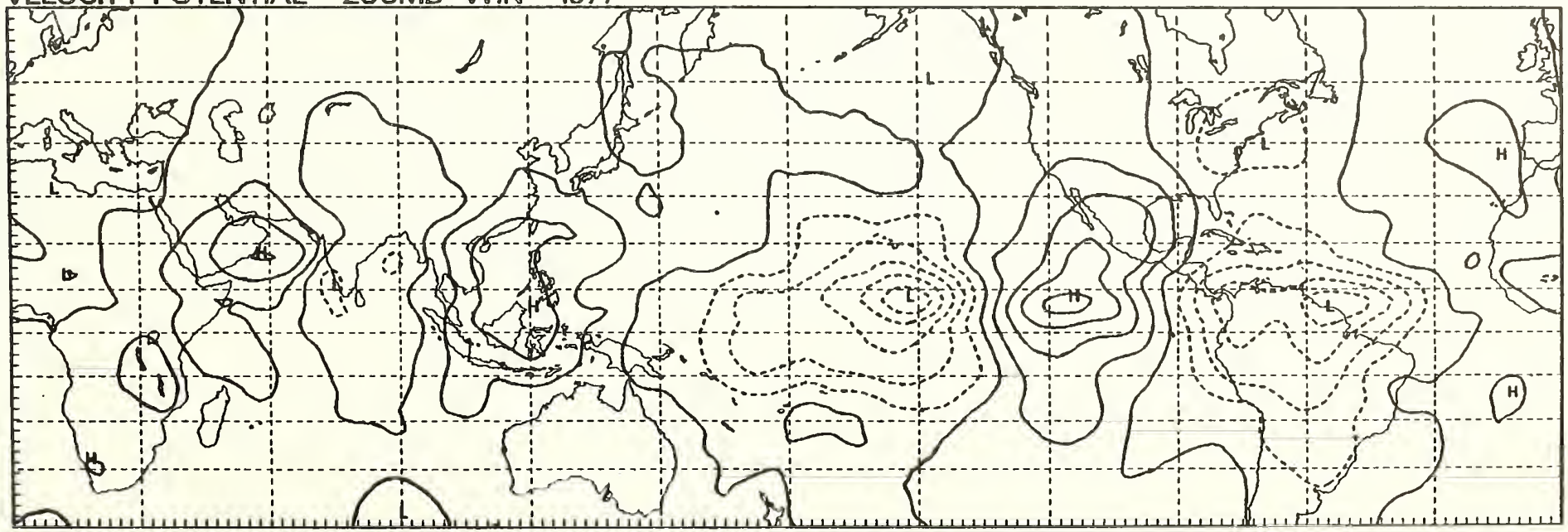

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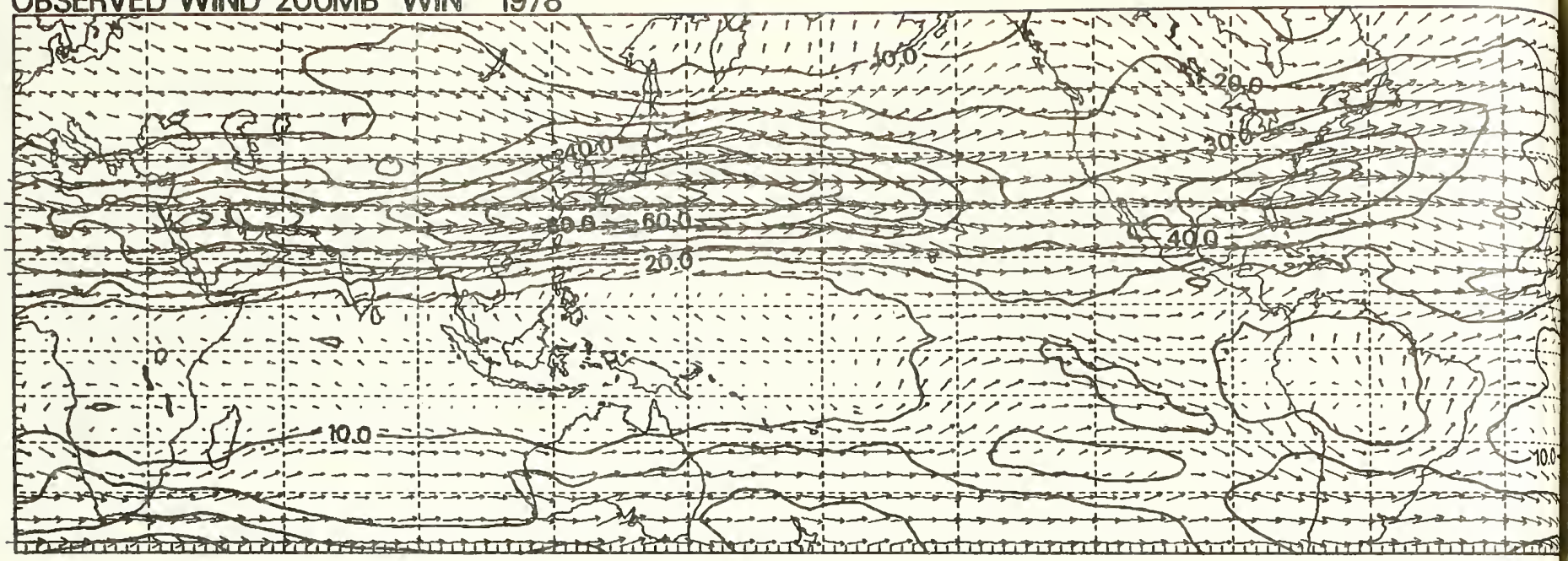

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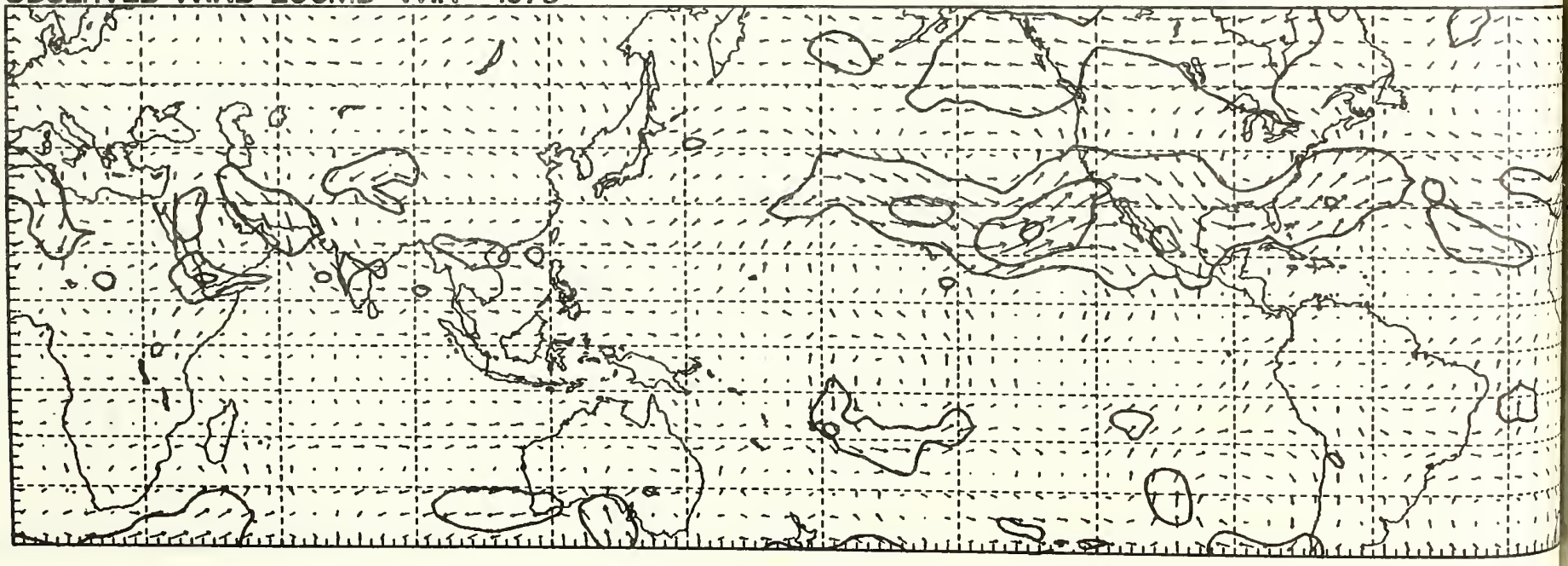
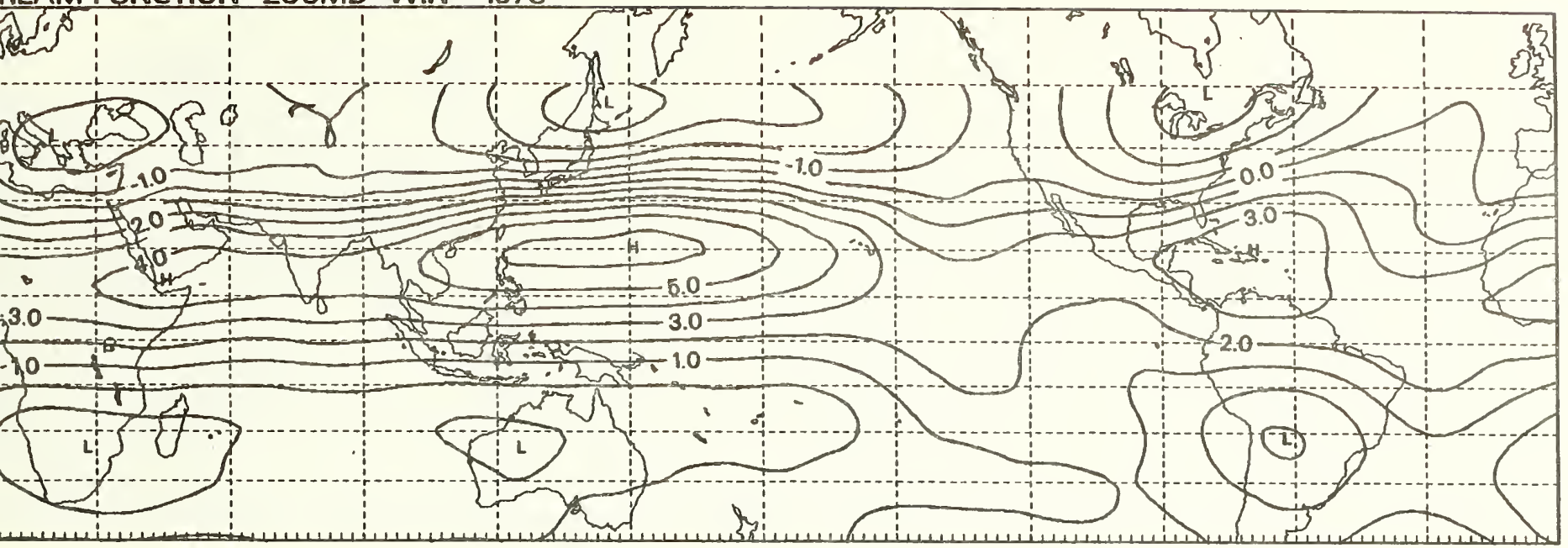


REAM FUNCTION 200MB WIN 1978



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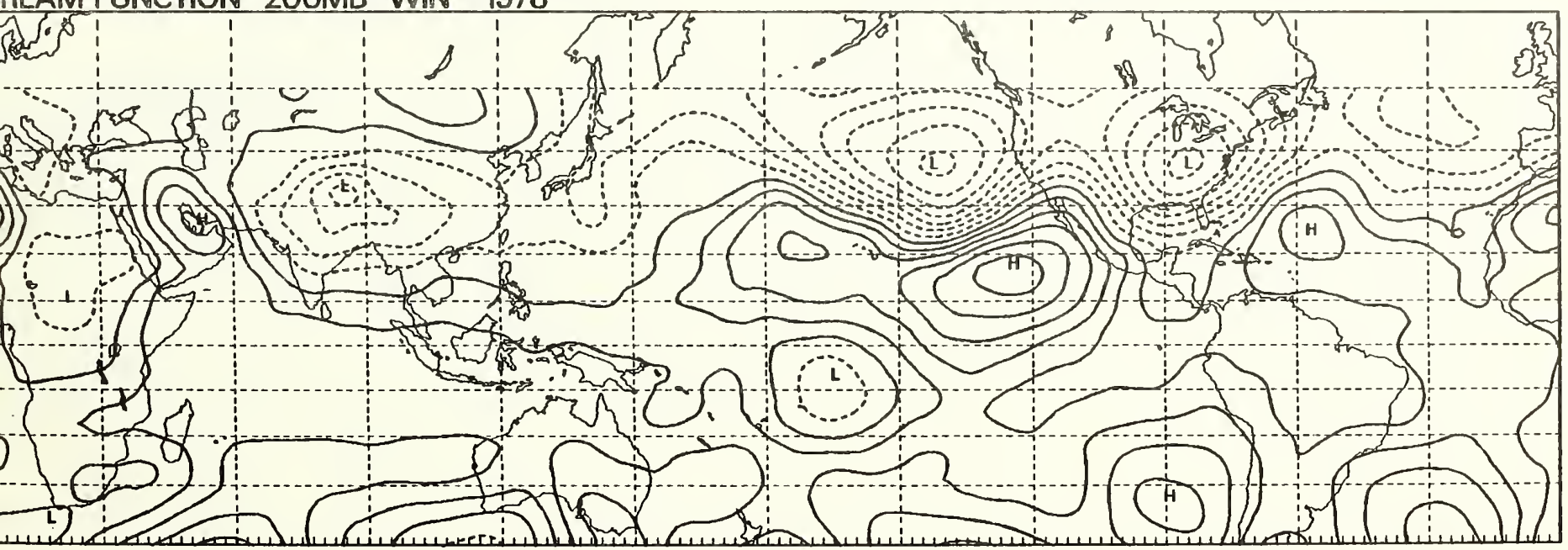

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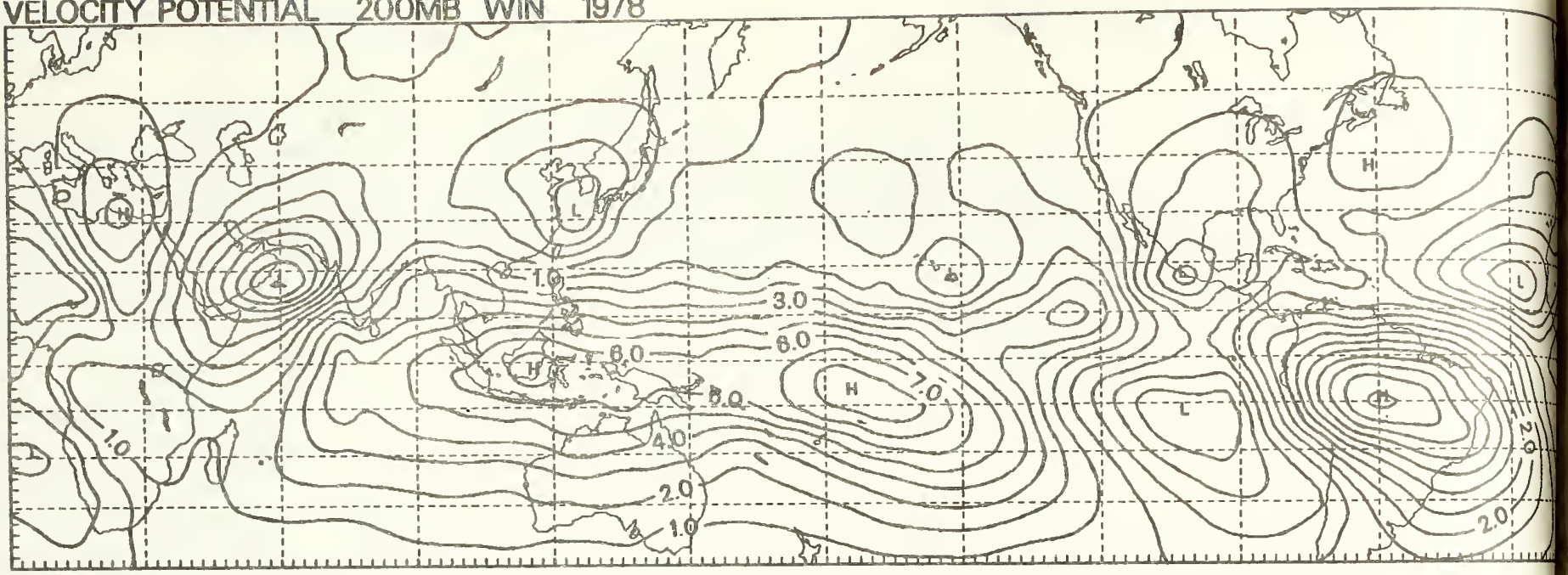
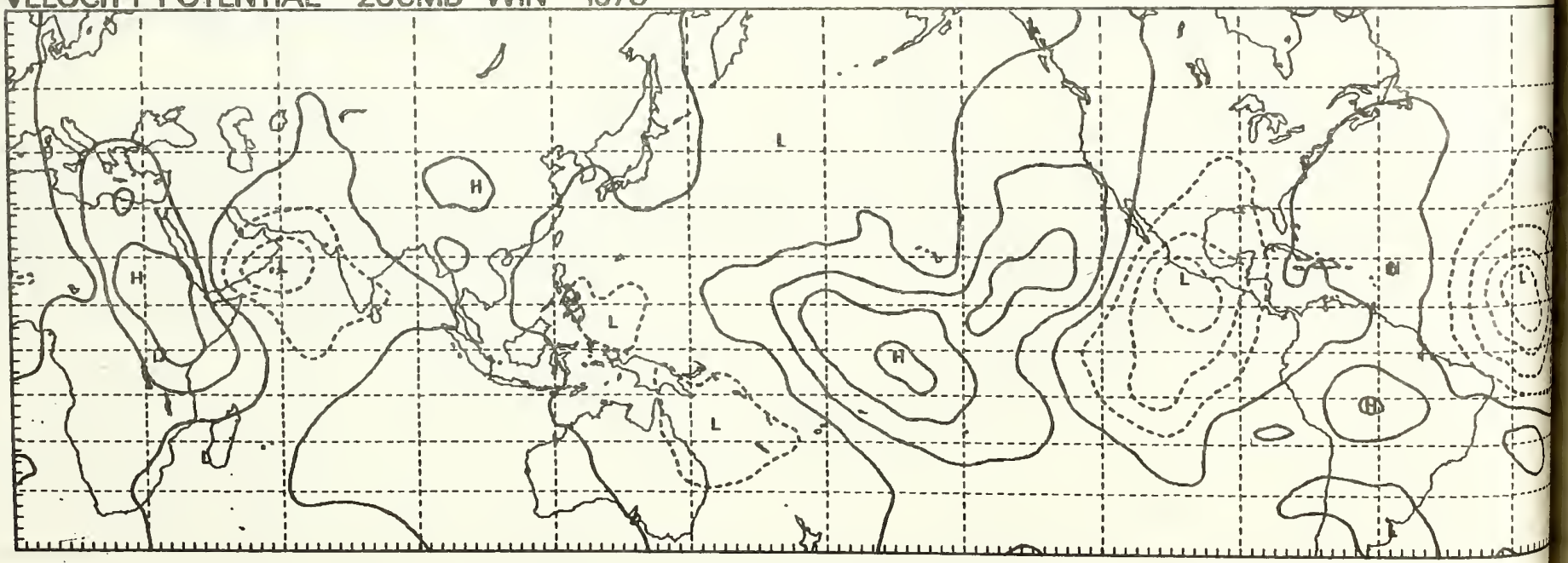


VELOCITY POTENTIAL 200MB WIN 1978



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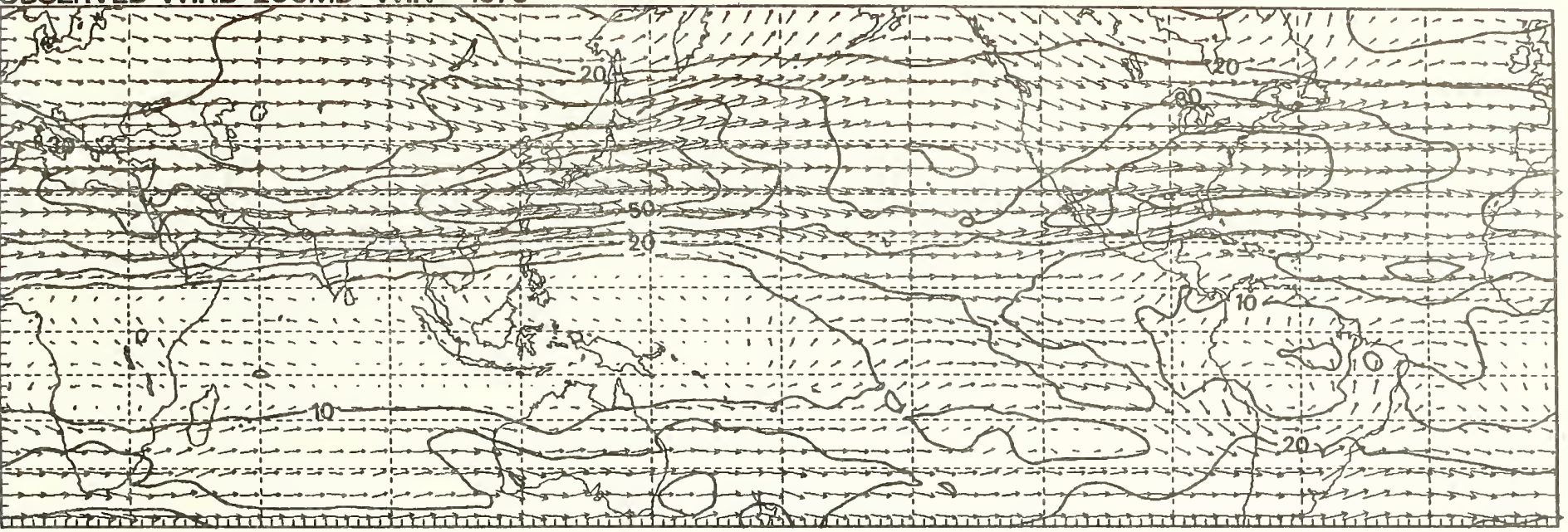

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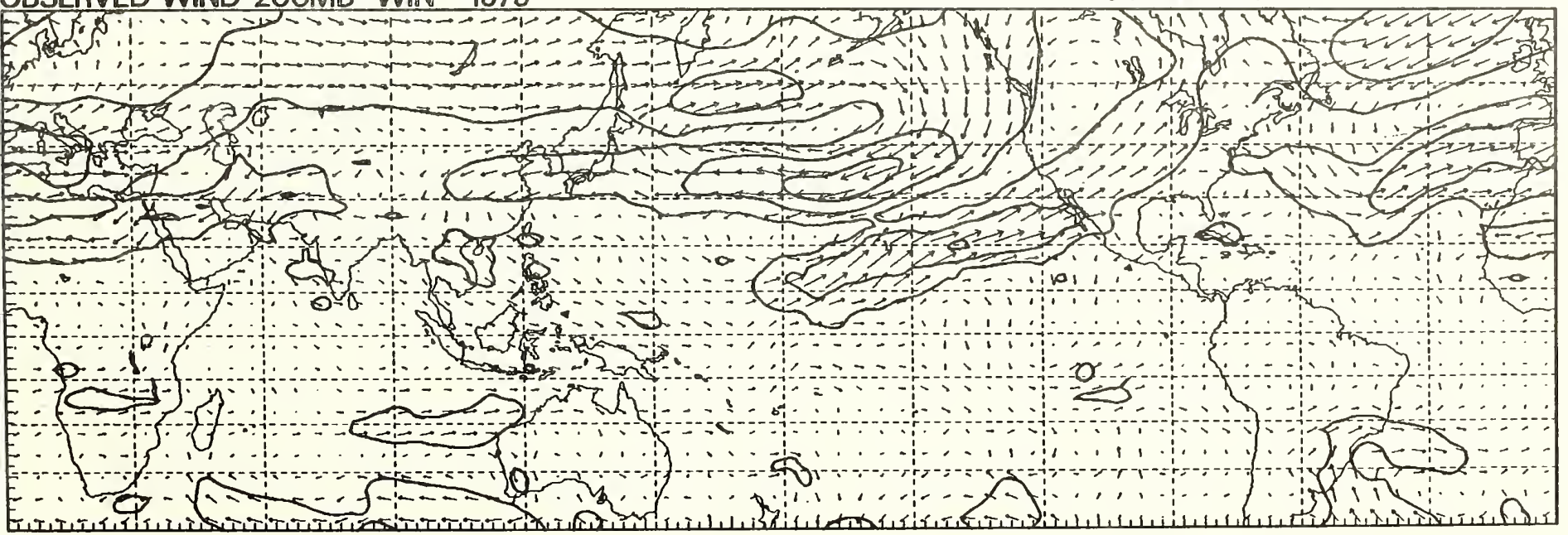
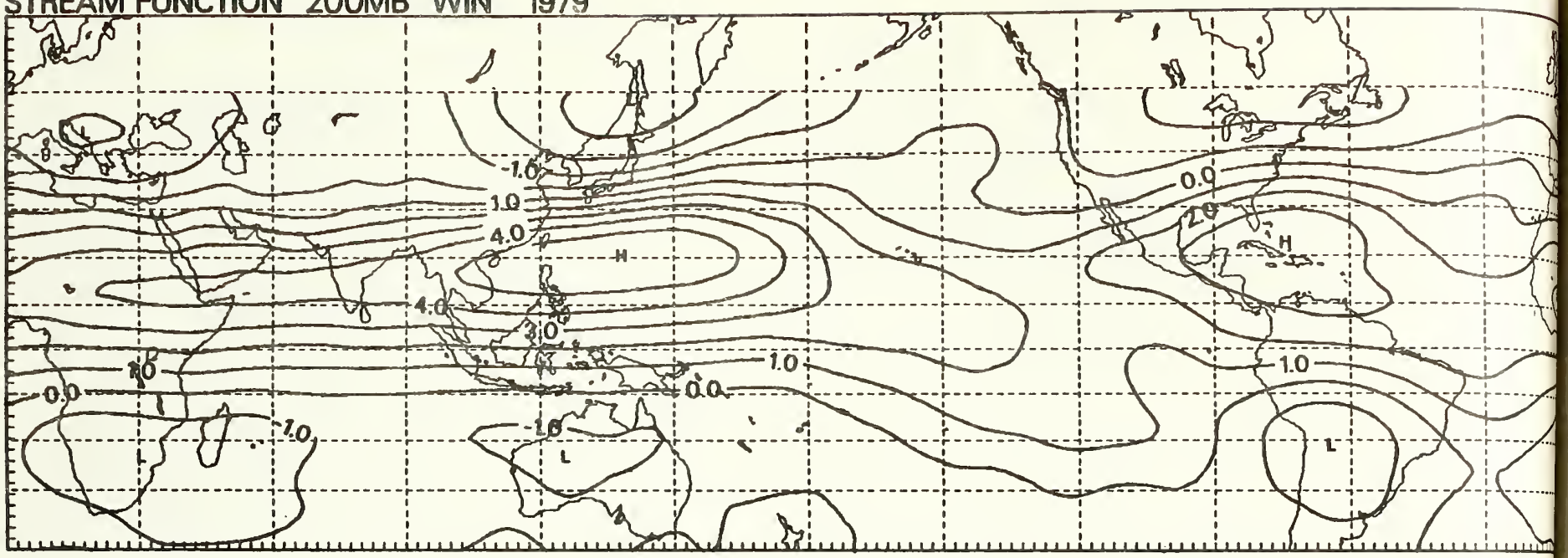


STREAM FUNCTION 200MB WIN 1979



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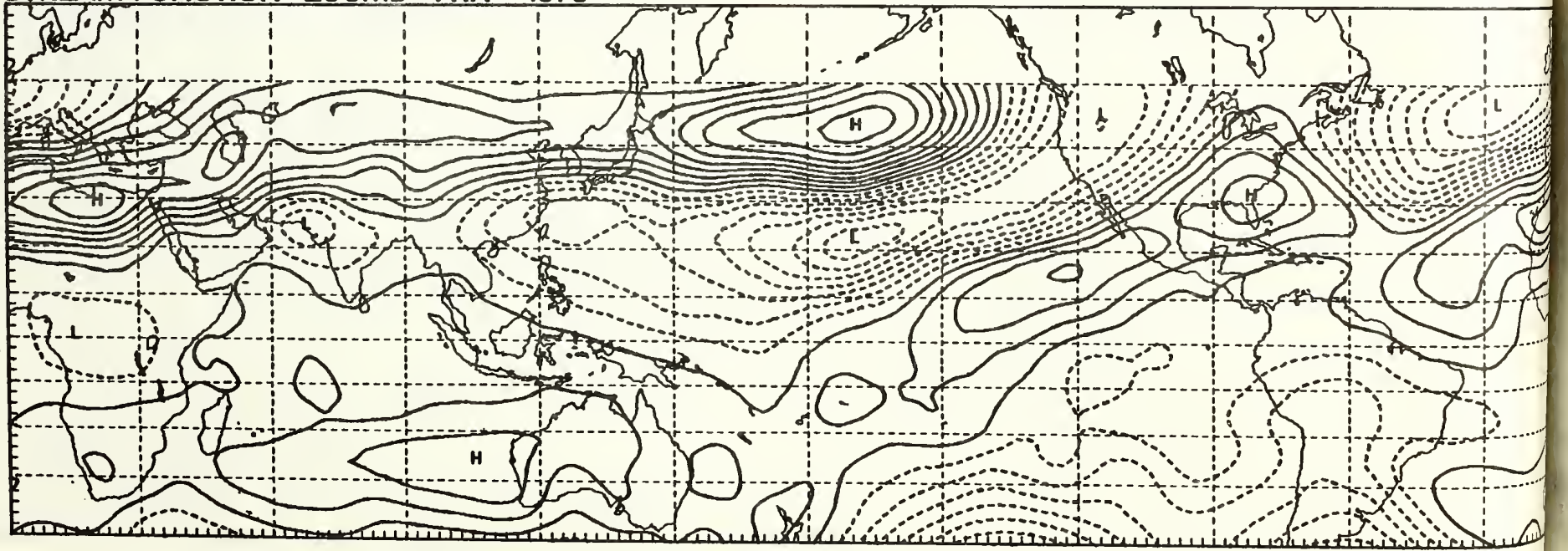
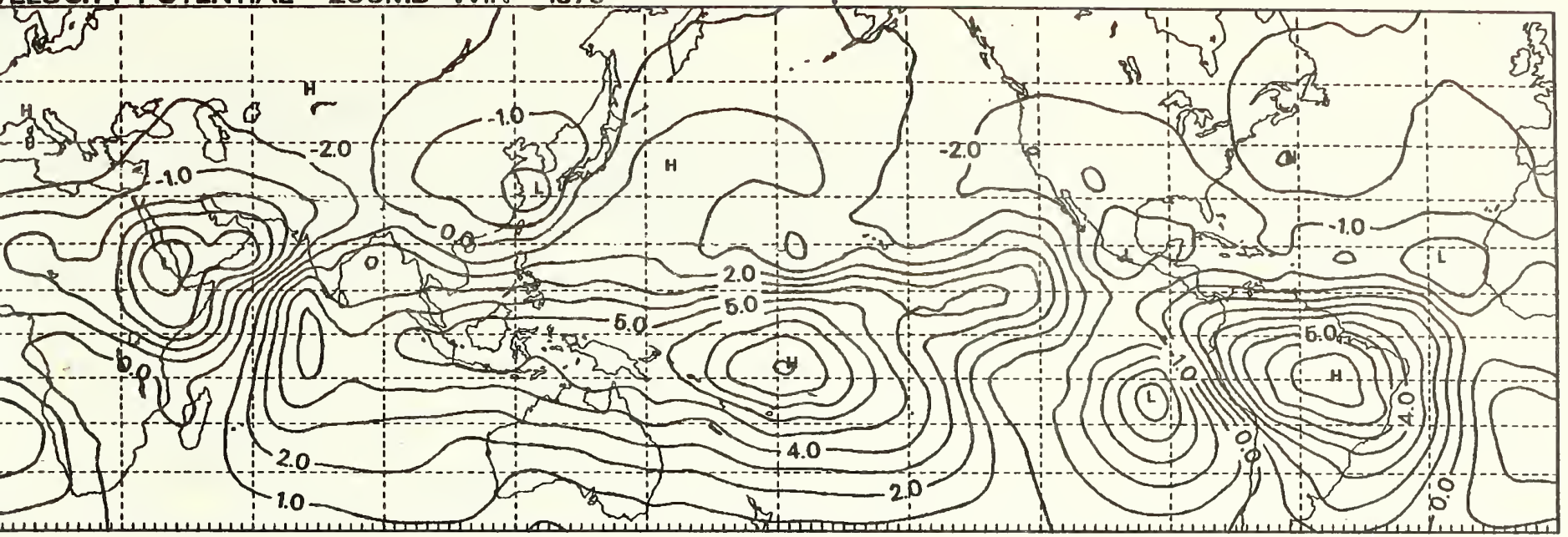
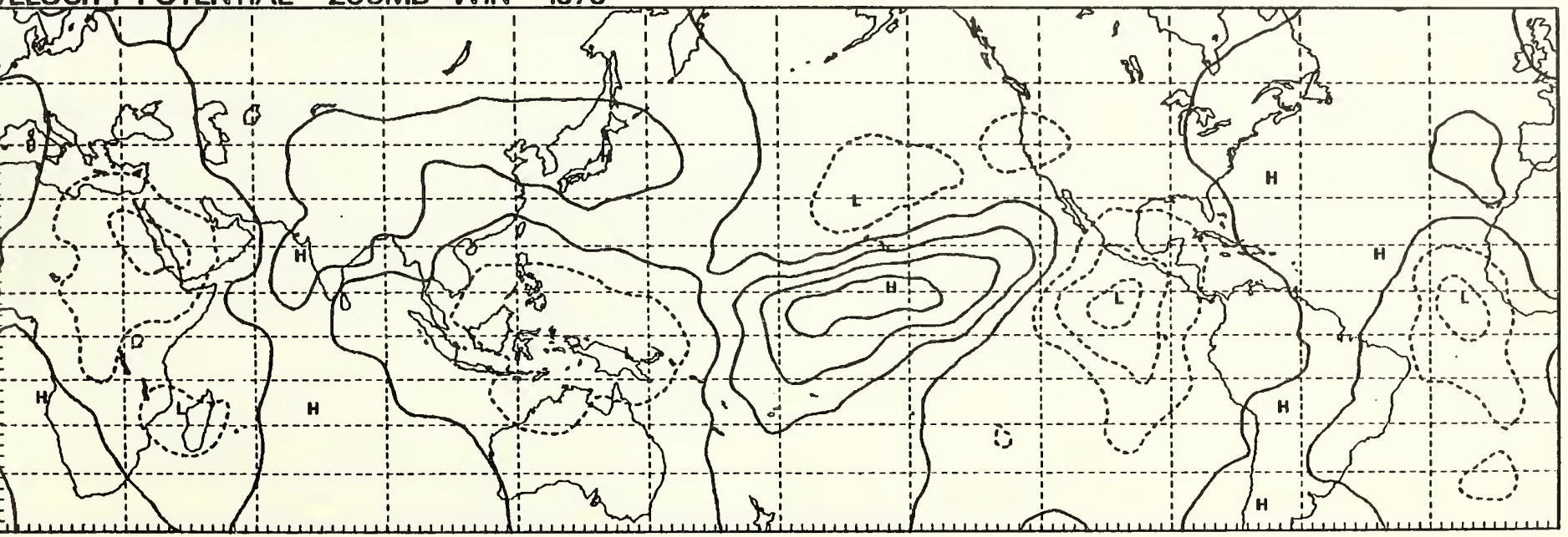


VELOCITY POTENTIAL 200MB WIN 1979



VELOCITY POTENTIAL 200MB WIN 1979



OBSERVED WIND 200MB WIN 1980

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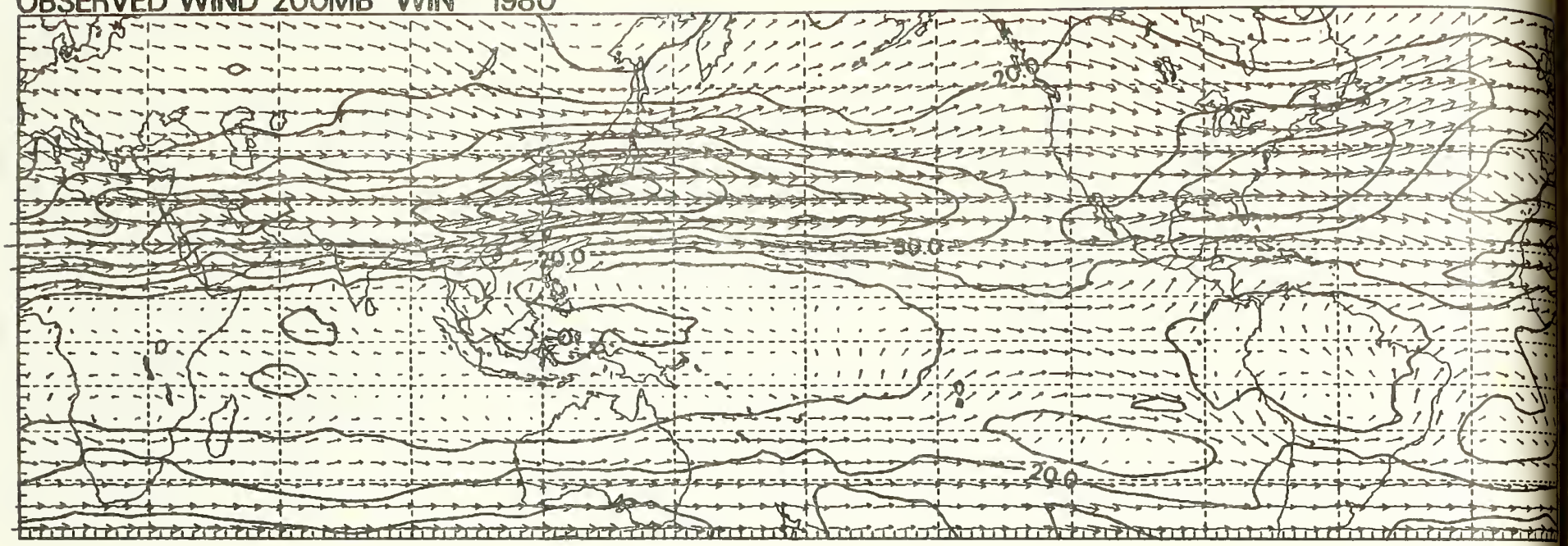

OBSERVED WIND 200MB WIN 1980

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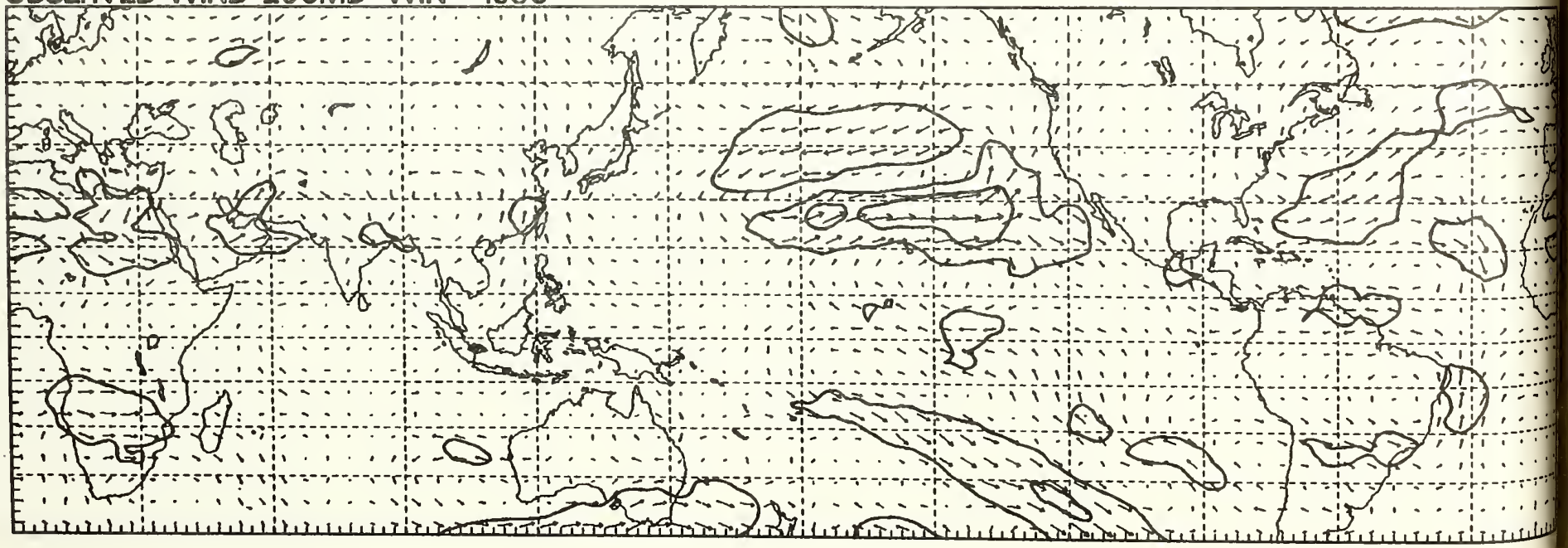
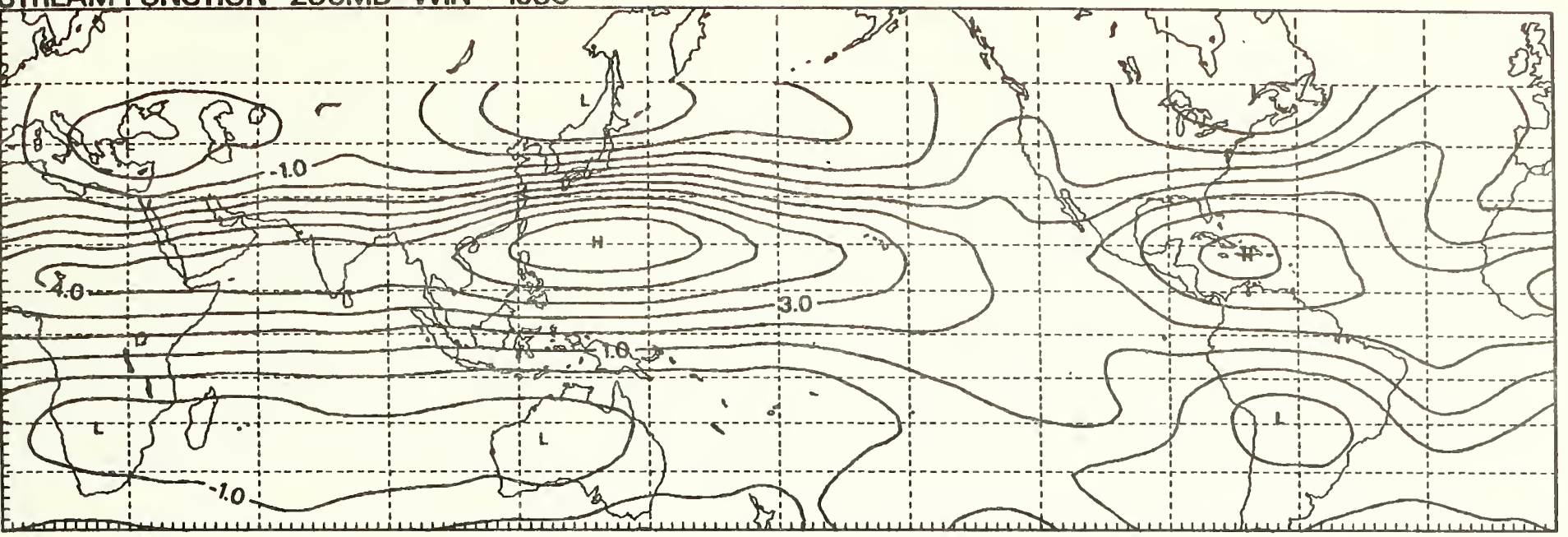


STREAM FUNCTION 200MB WIN 1980



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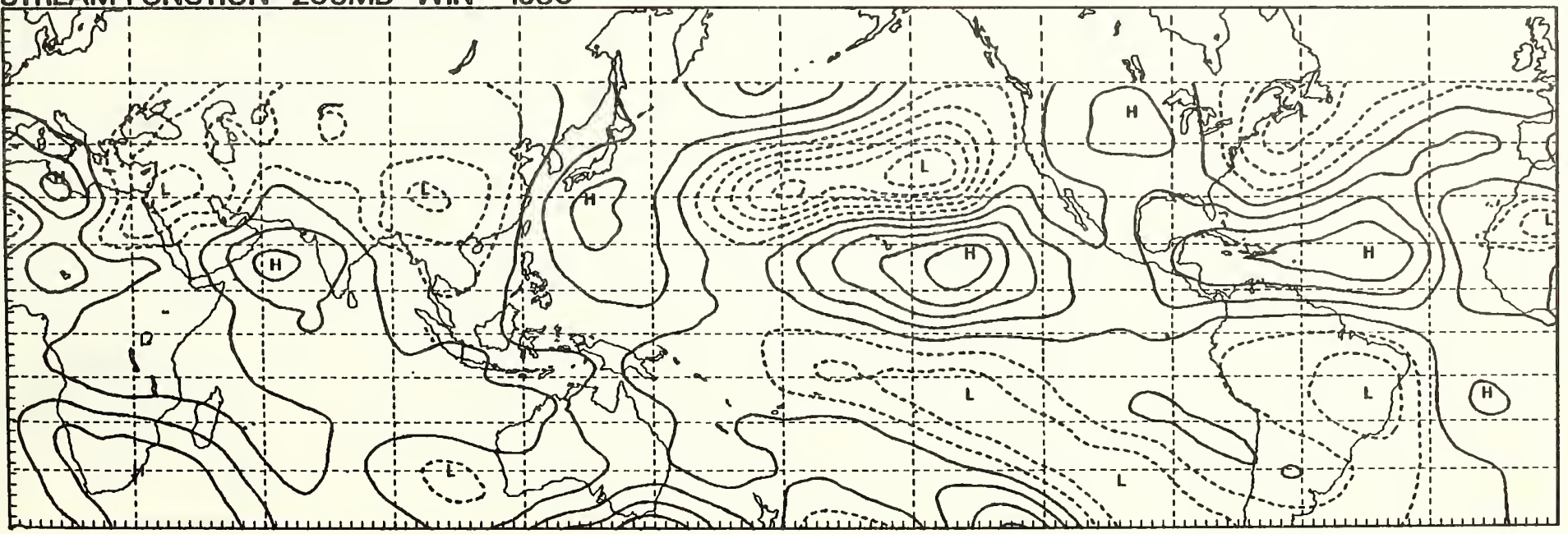
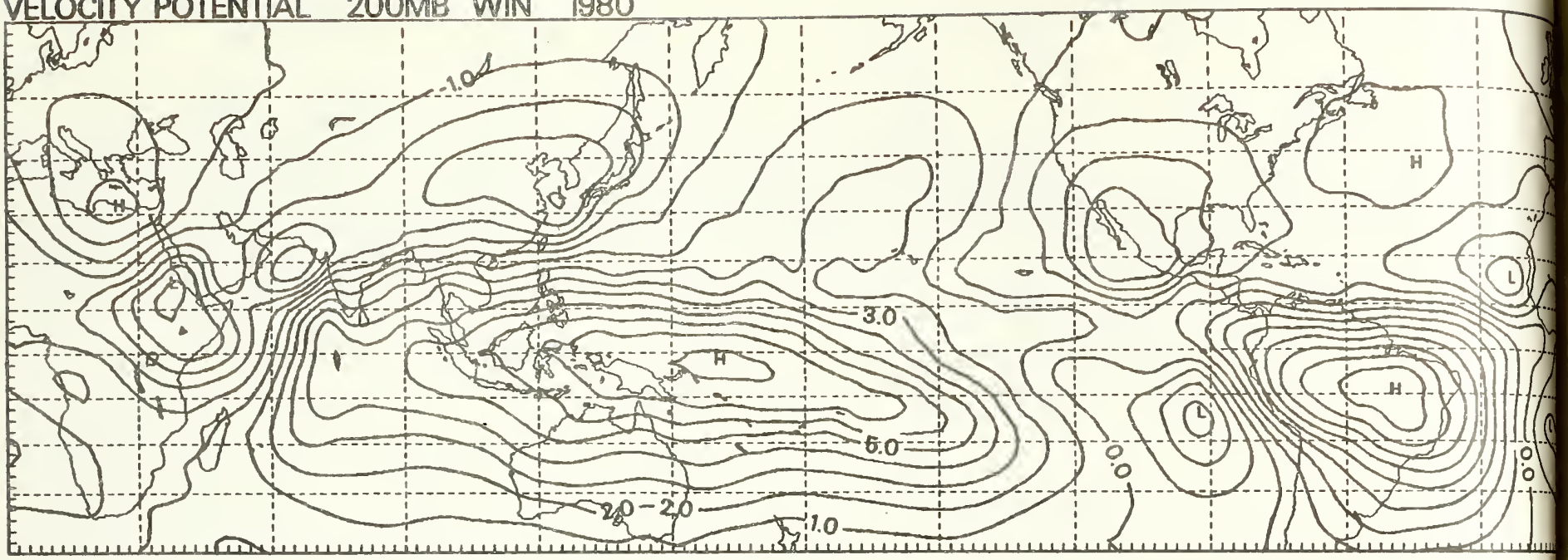


VELOCITY POTENTIAL 200MB WIN 1980



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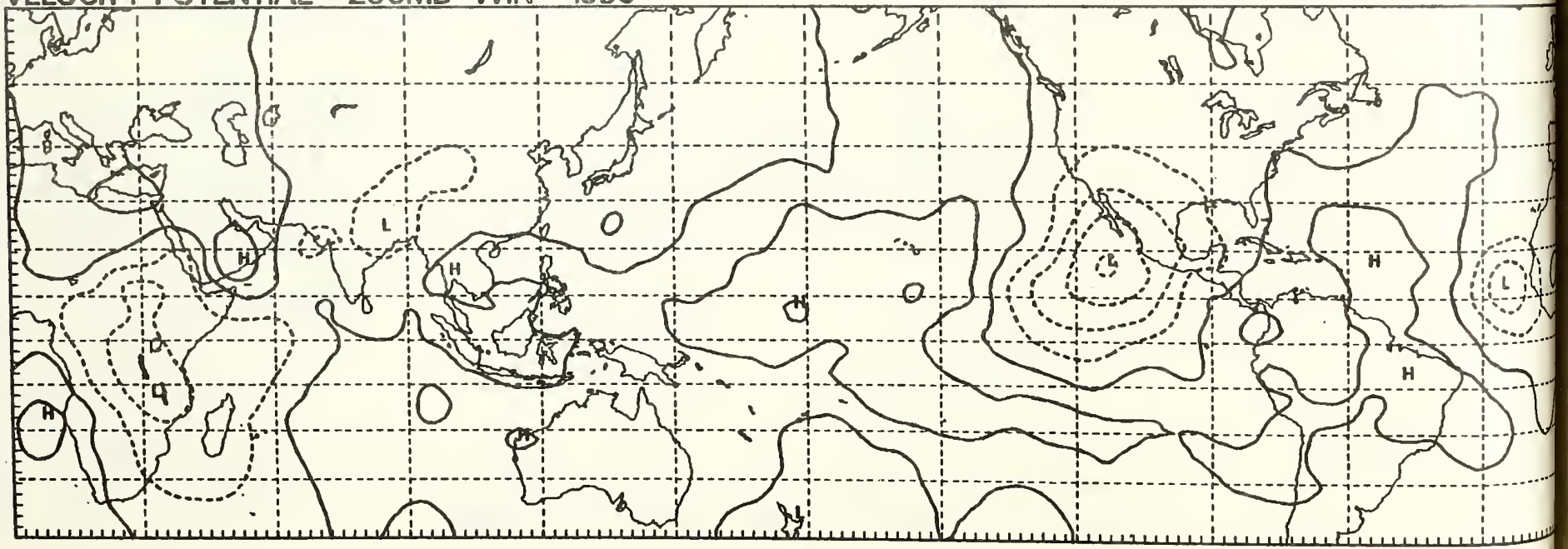
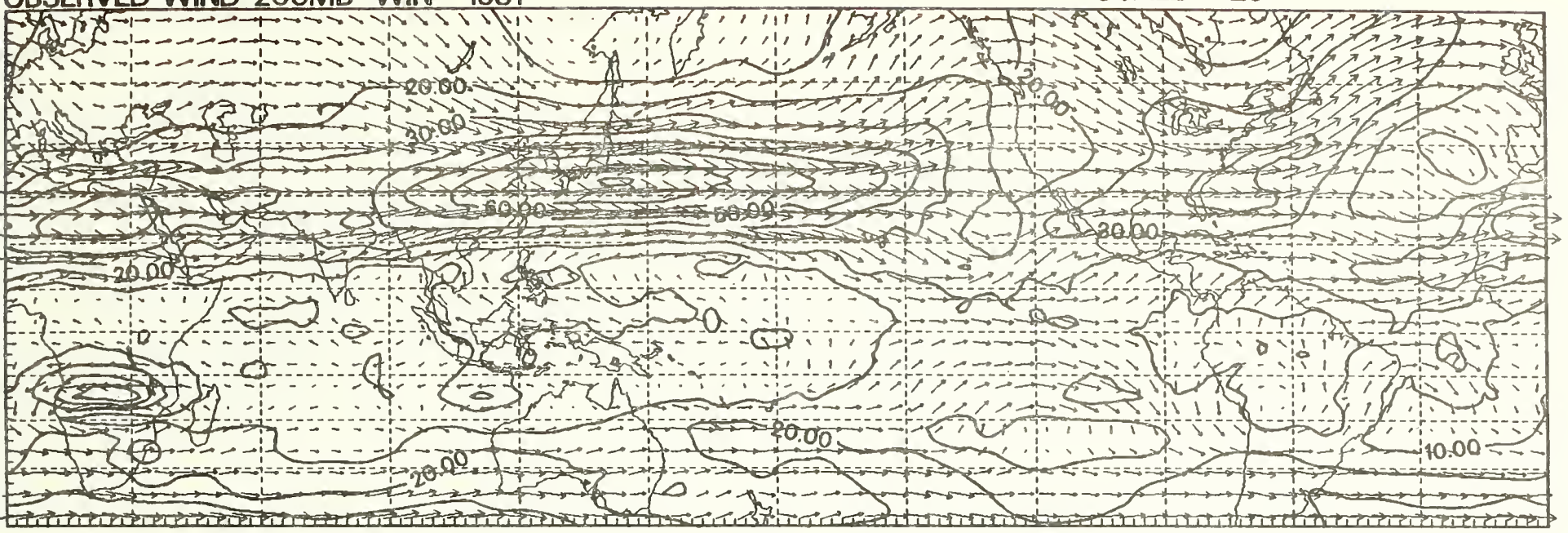


OBSERVED WIND 200MB WIN 1981 SCALE = 20



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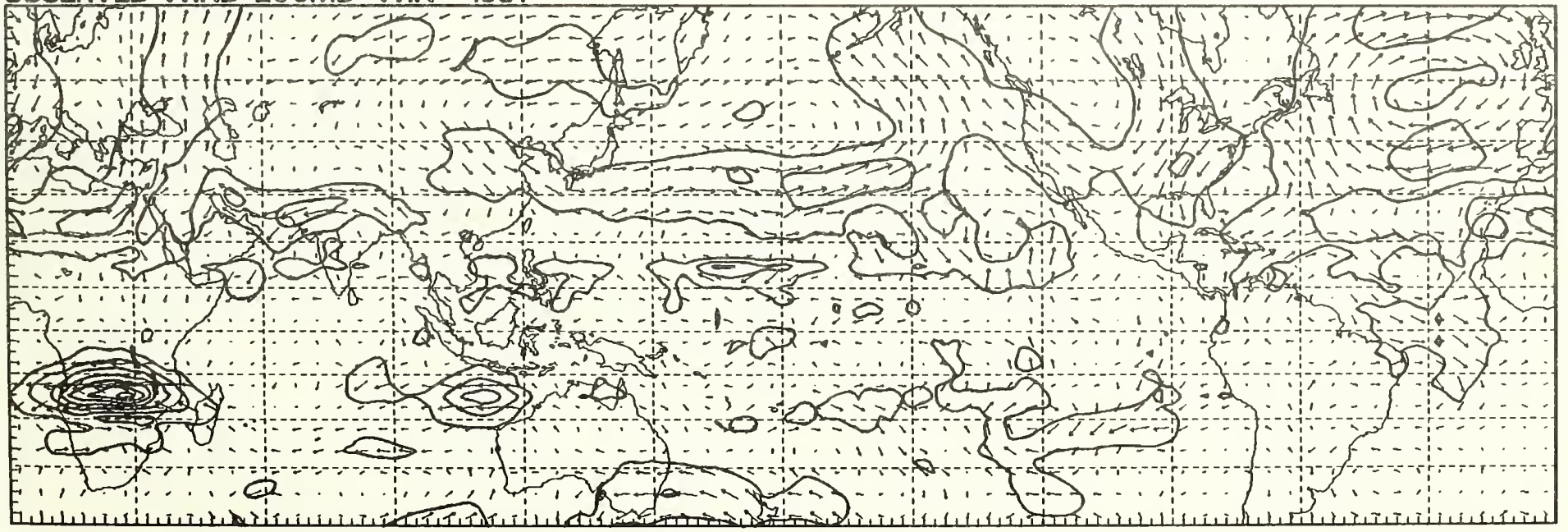
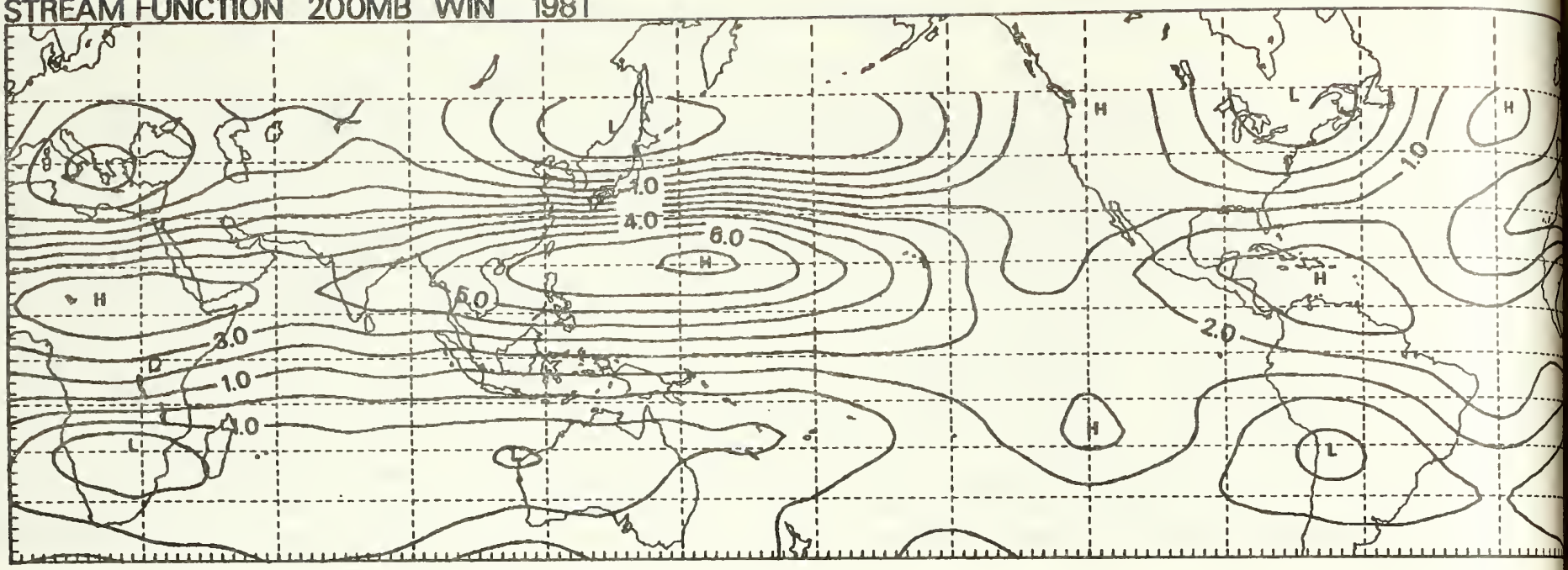
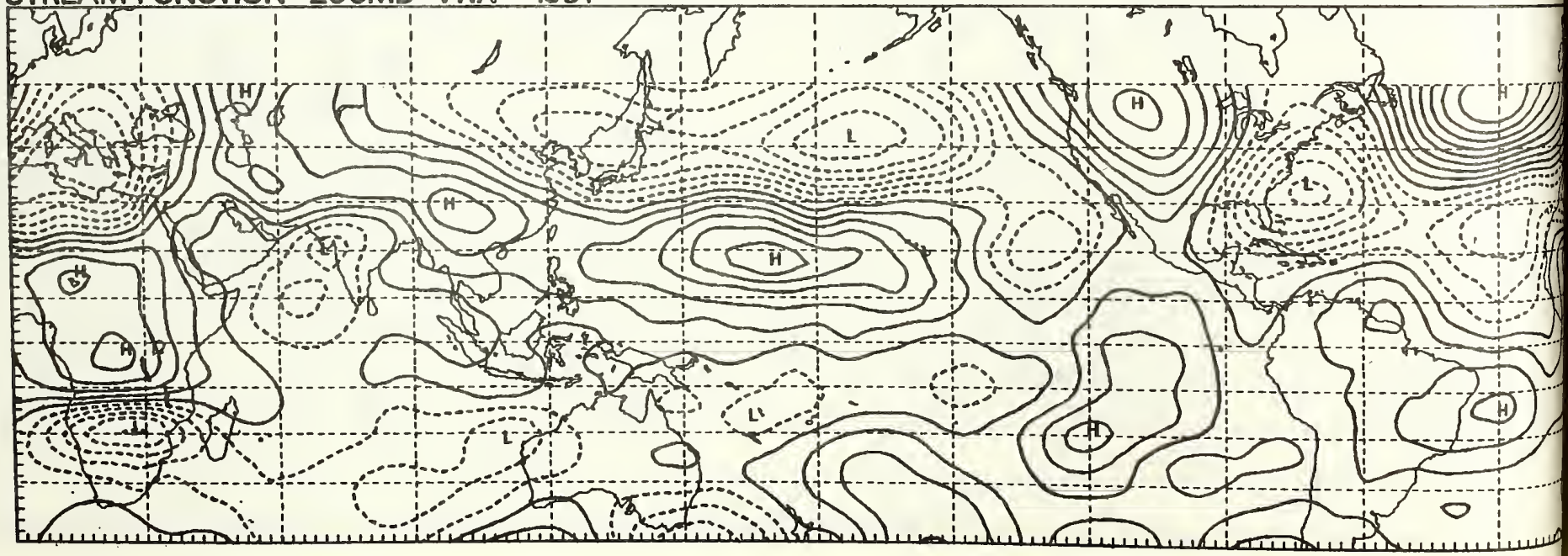


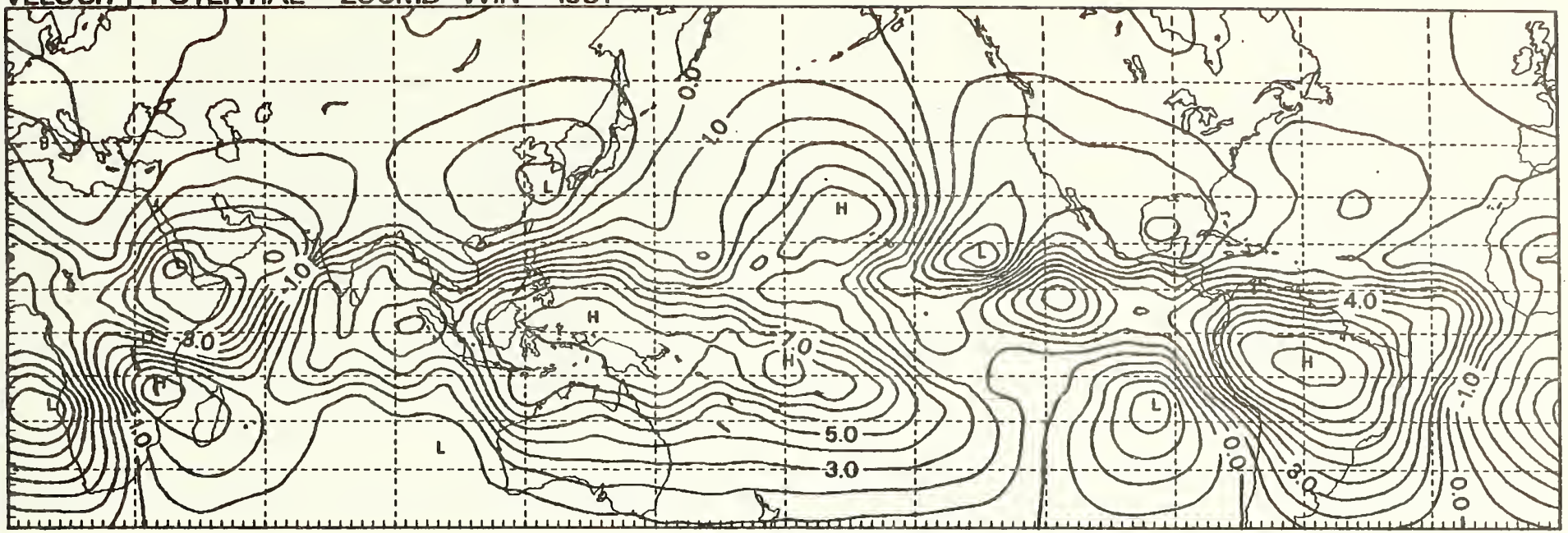
STREAM FUNCTION 200MB WIN 1981



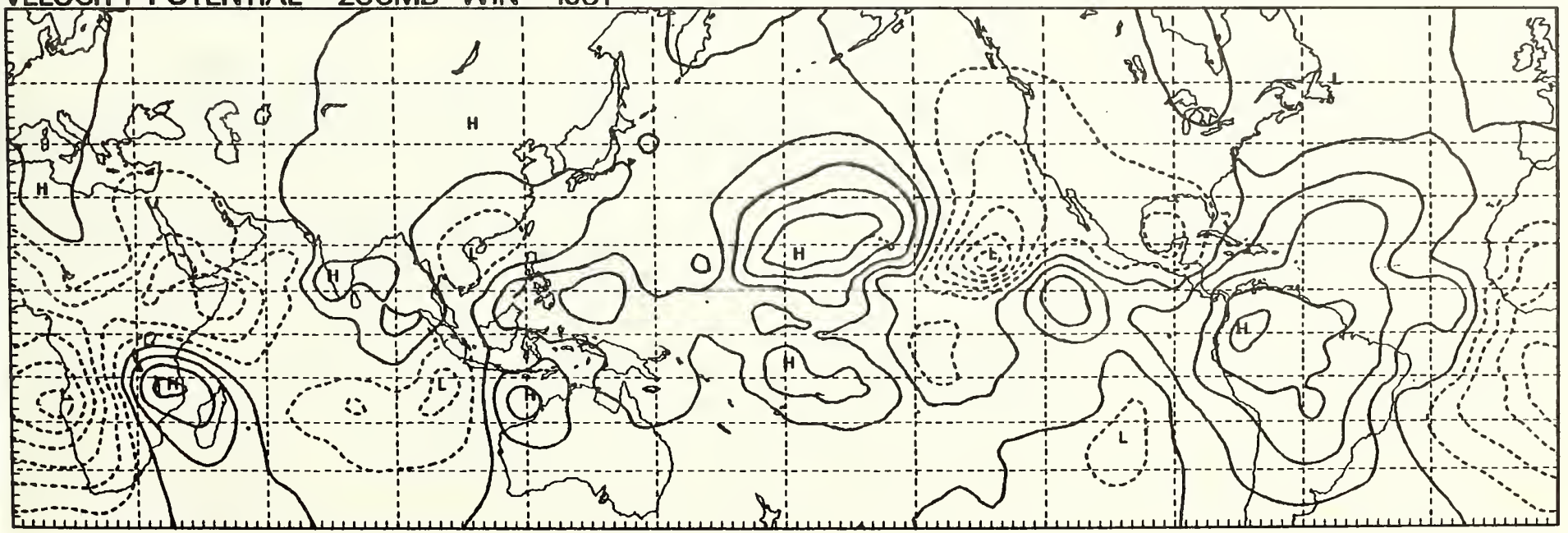
STREAM FUNCTION 200MB WIN 1981



VELOCITY POTENTIAL 200MB WIN 1981



VELOCITY POTENTIAL 200MB WIN 1981



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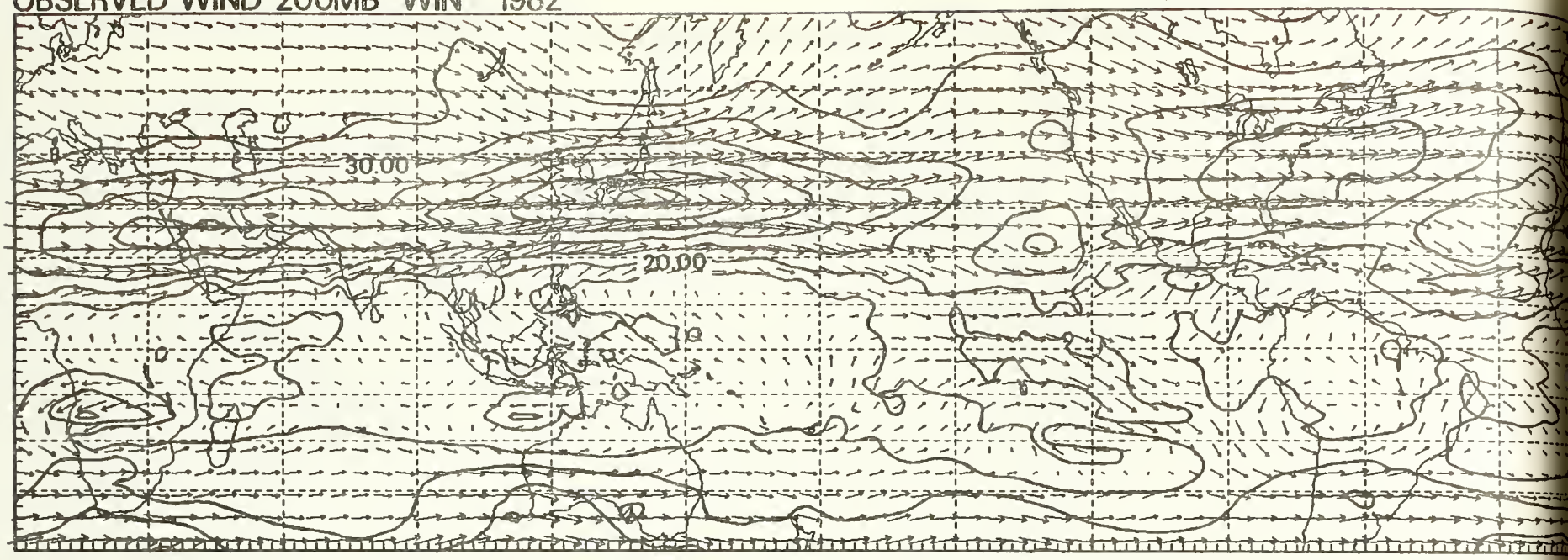

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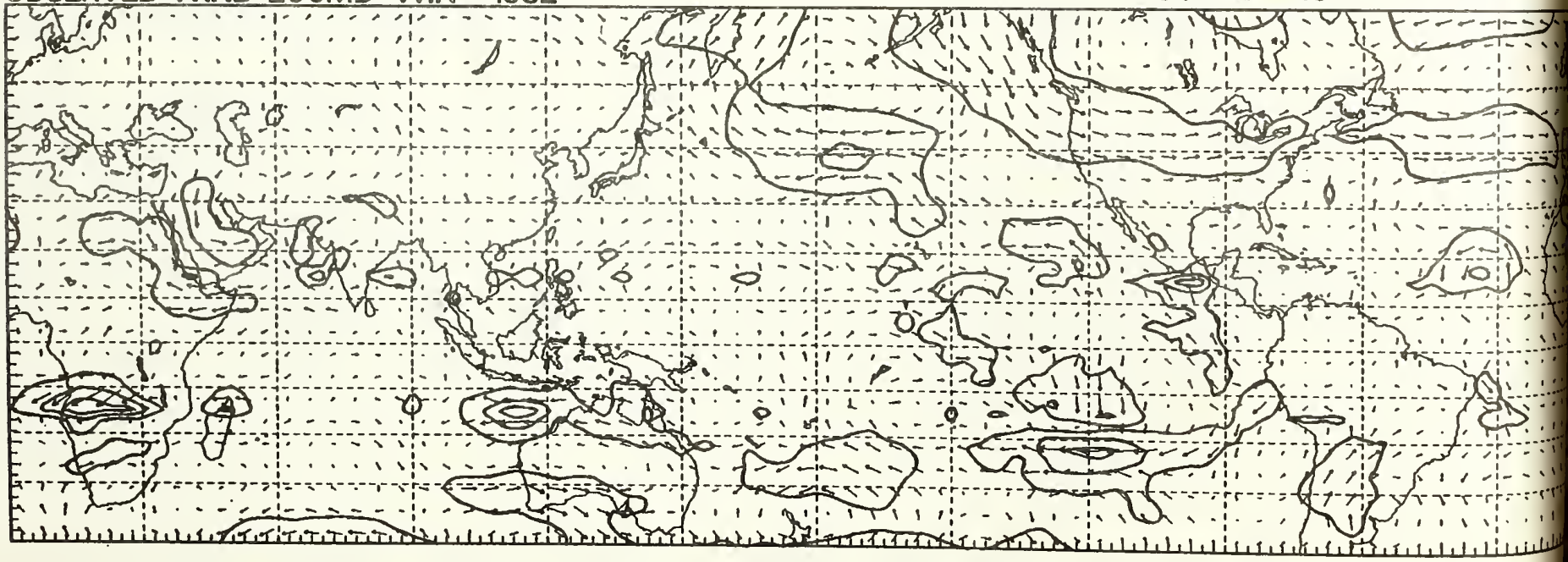
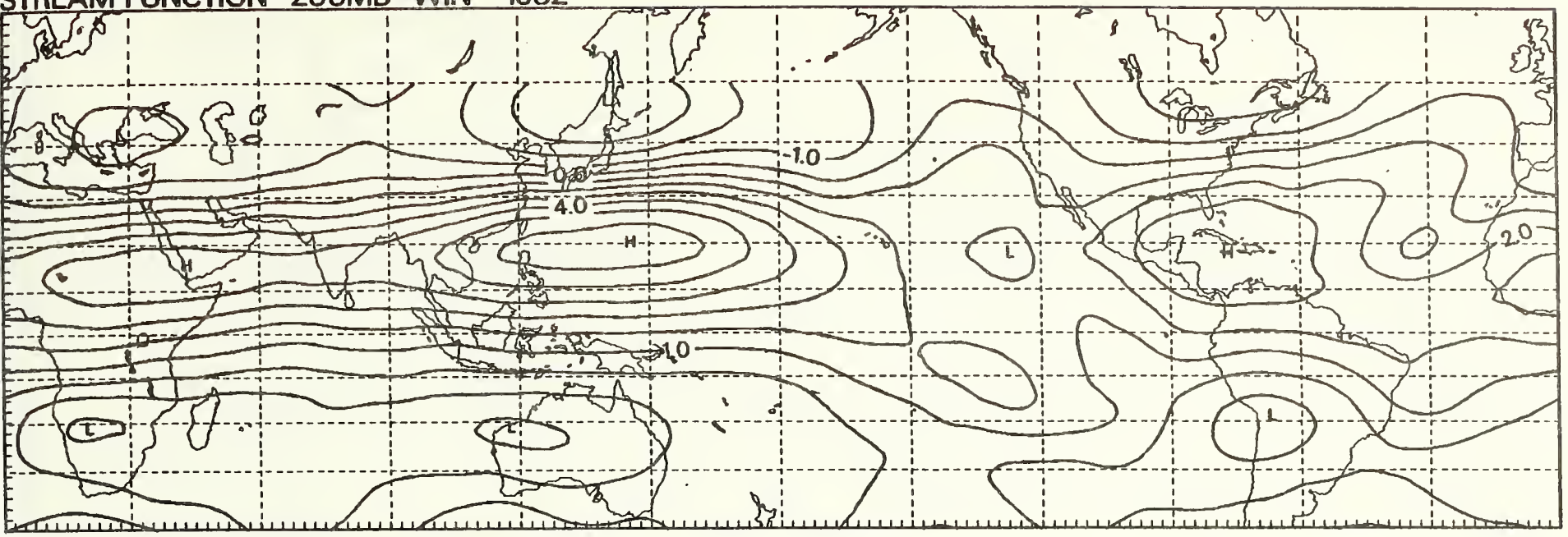
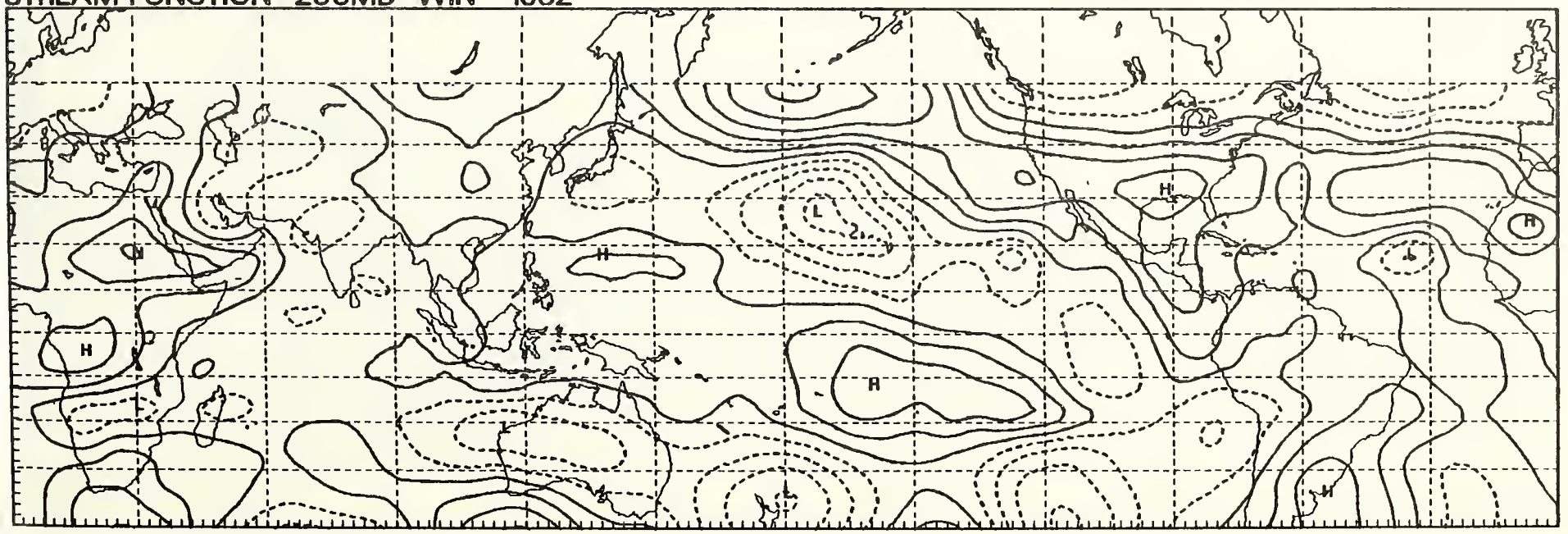


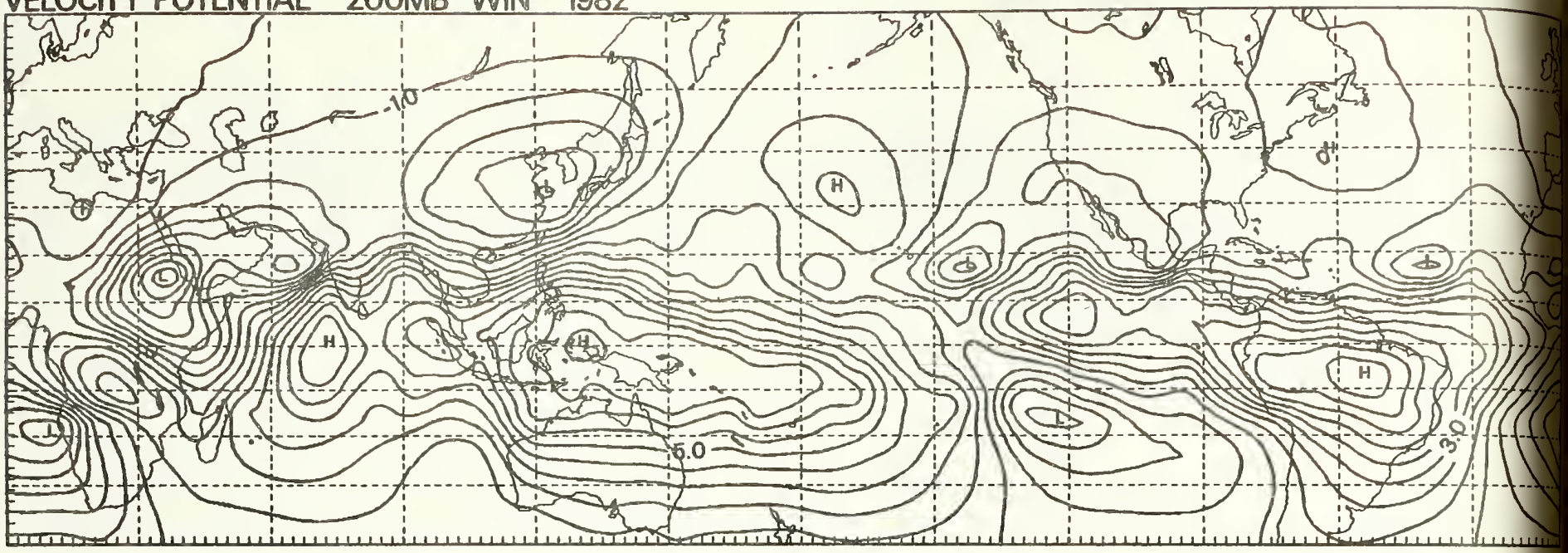
STREAM FUNCTION 200MB WIN 1982



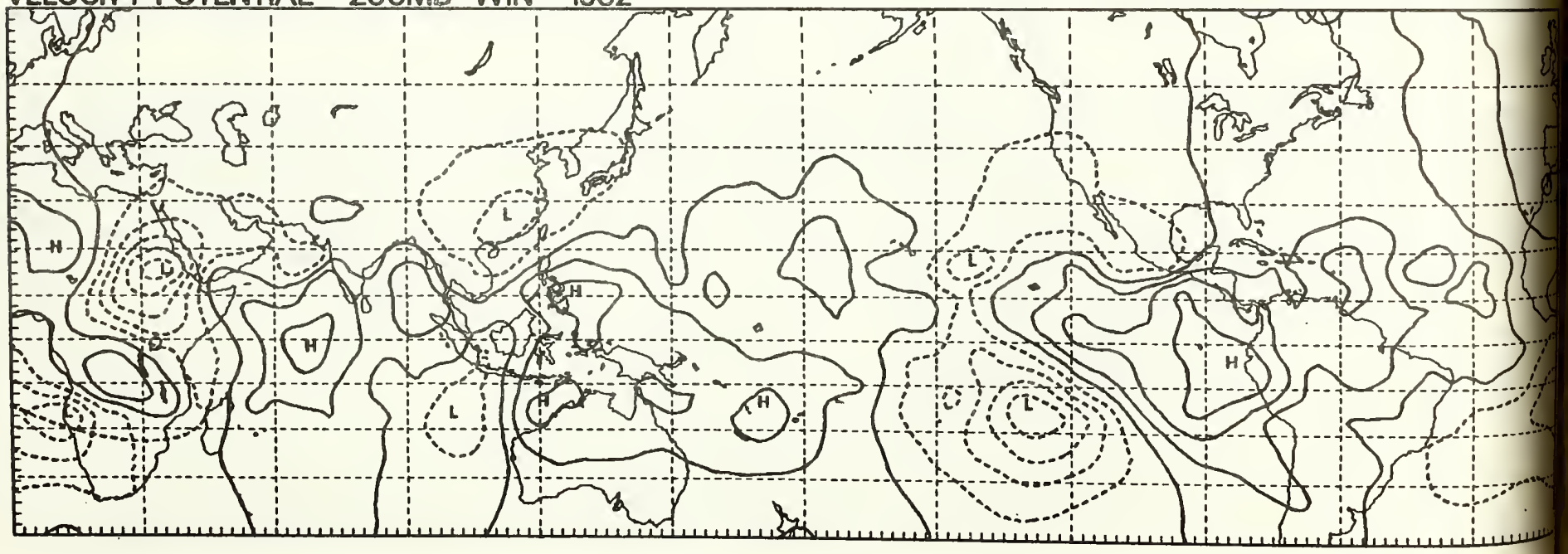
STREAM FUNCTION 200MB WIN 1982



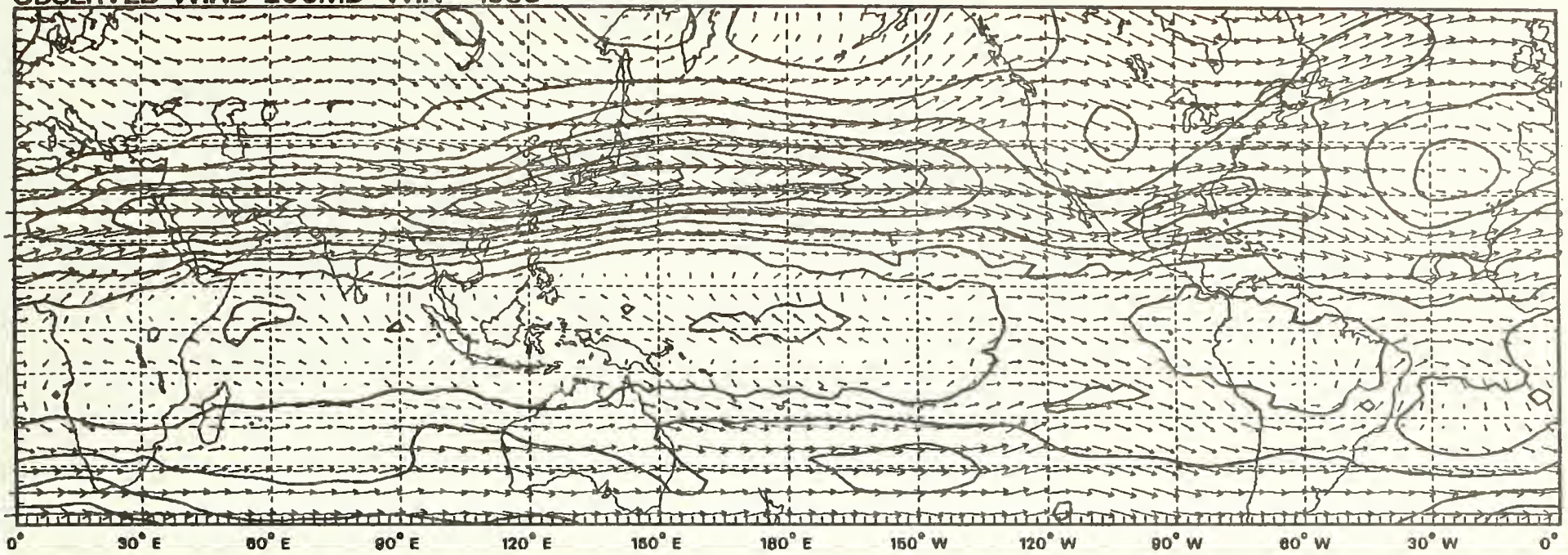
VELOCITY POTENTIAL 200MB WIN 1982



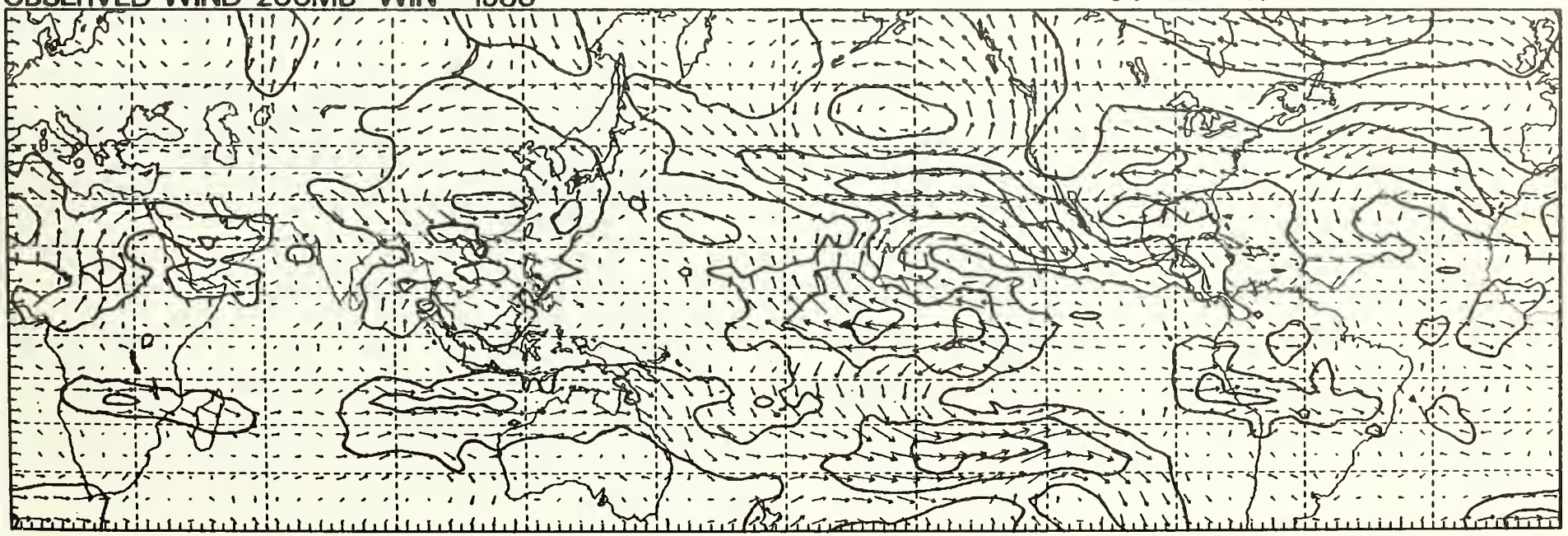
VELOCITY POTENTIAL 200MB WIN 1982



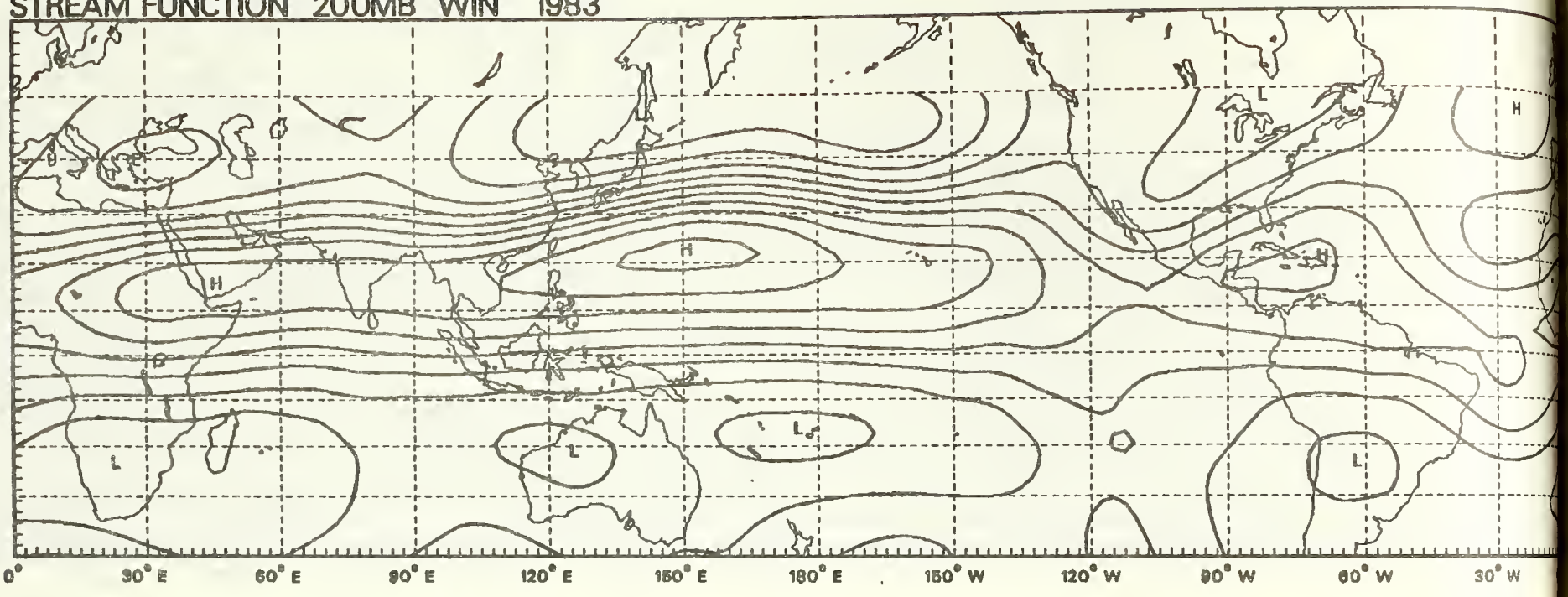
OBSERVED WIND 200MB WIN 1983 SCALE = 20



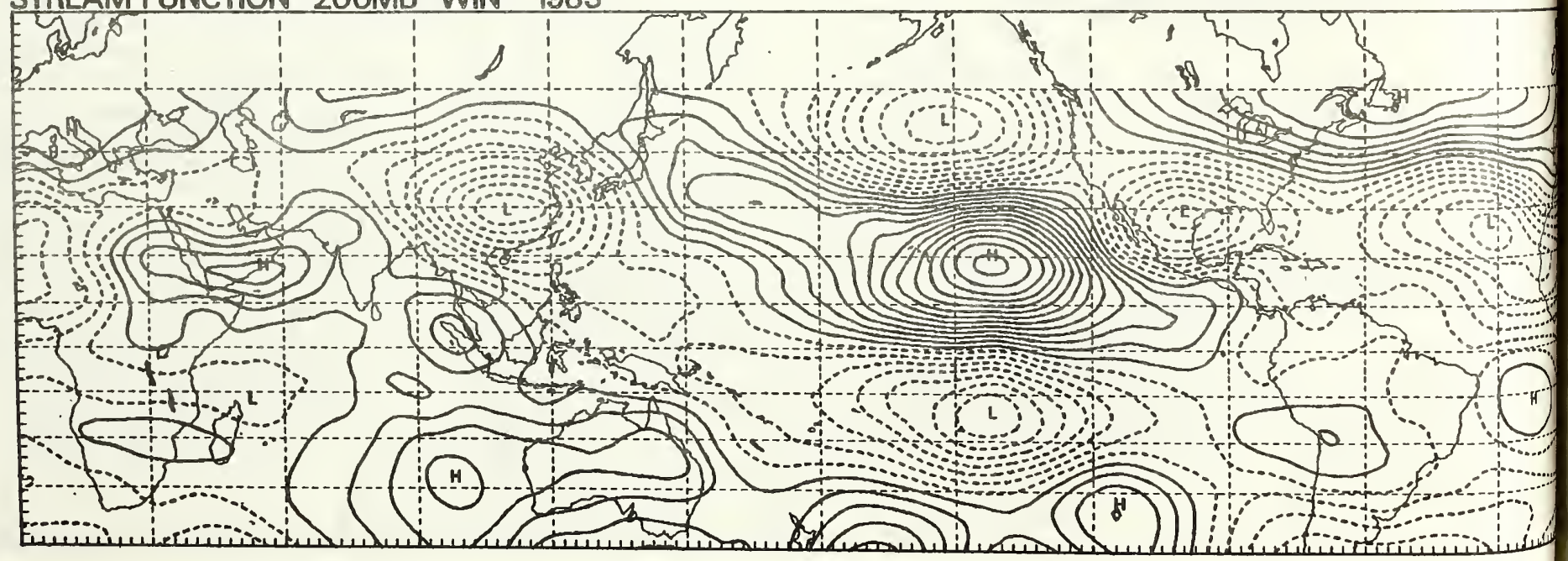
OBSERVED WIND 200MB WIN 1983 SCALE = 10



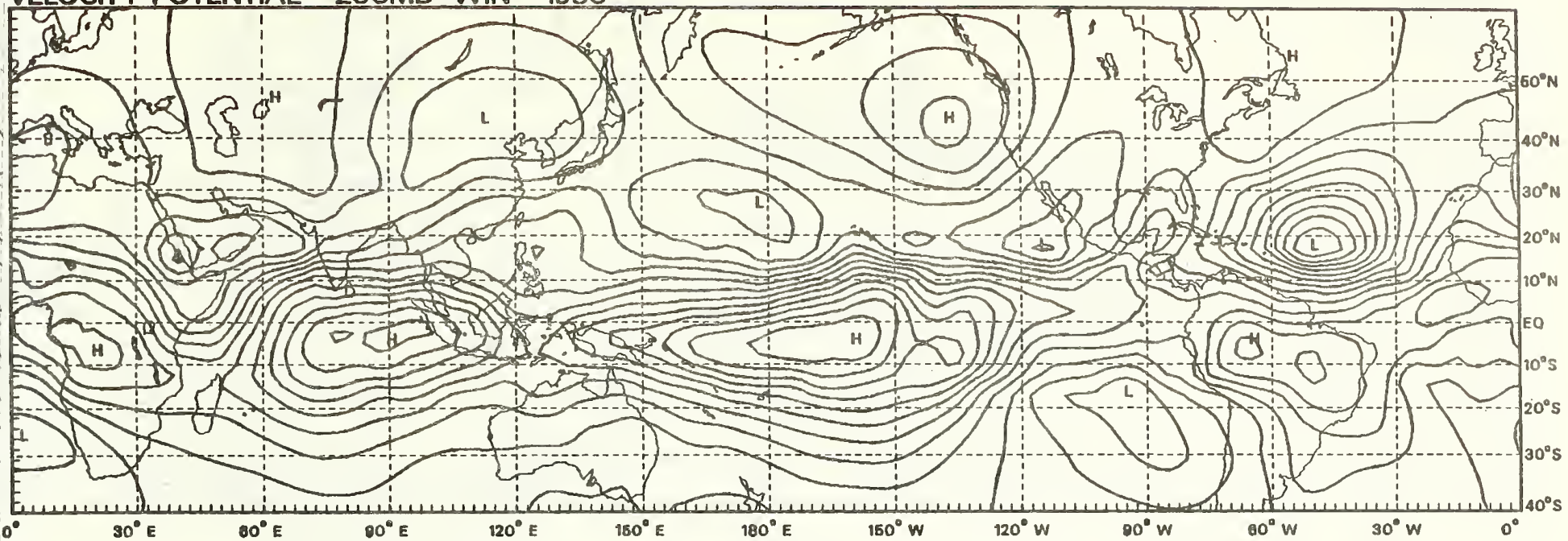
STREAM FUNCTION 200MB WIN 1983



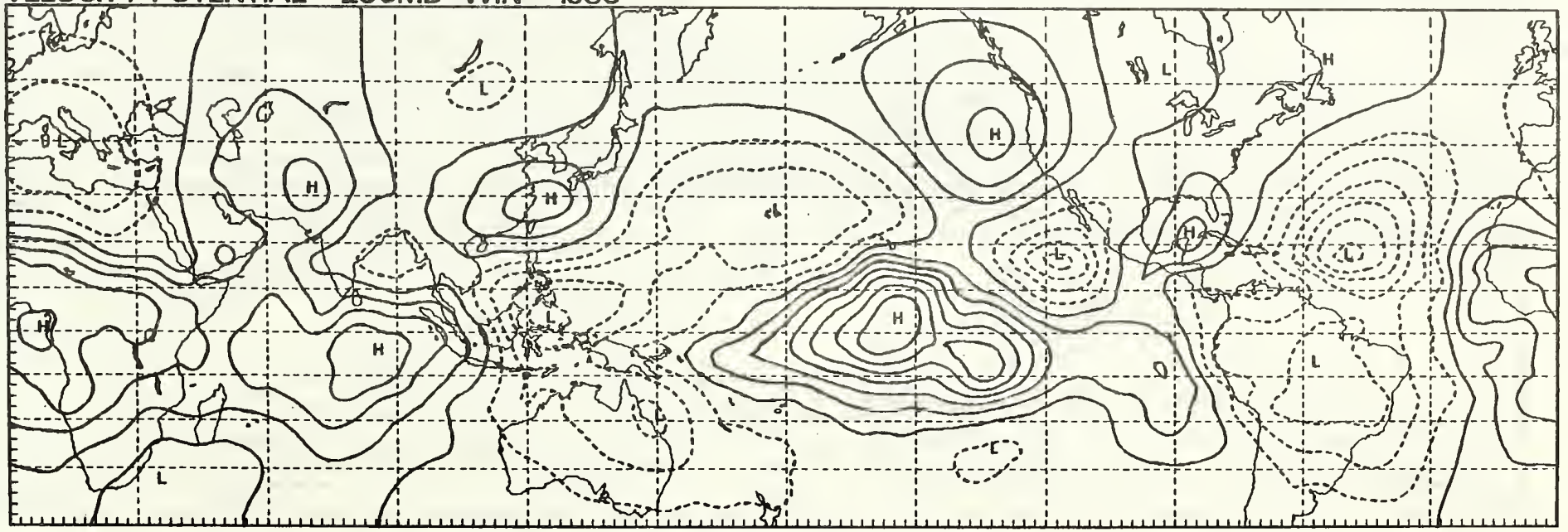
STREAM FUNCTION 200MB WIN 1983



VELOCITY POTENTIAL 200MB WIN 1983

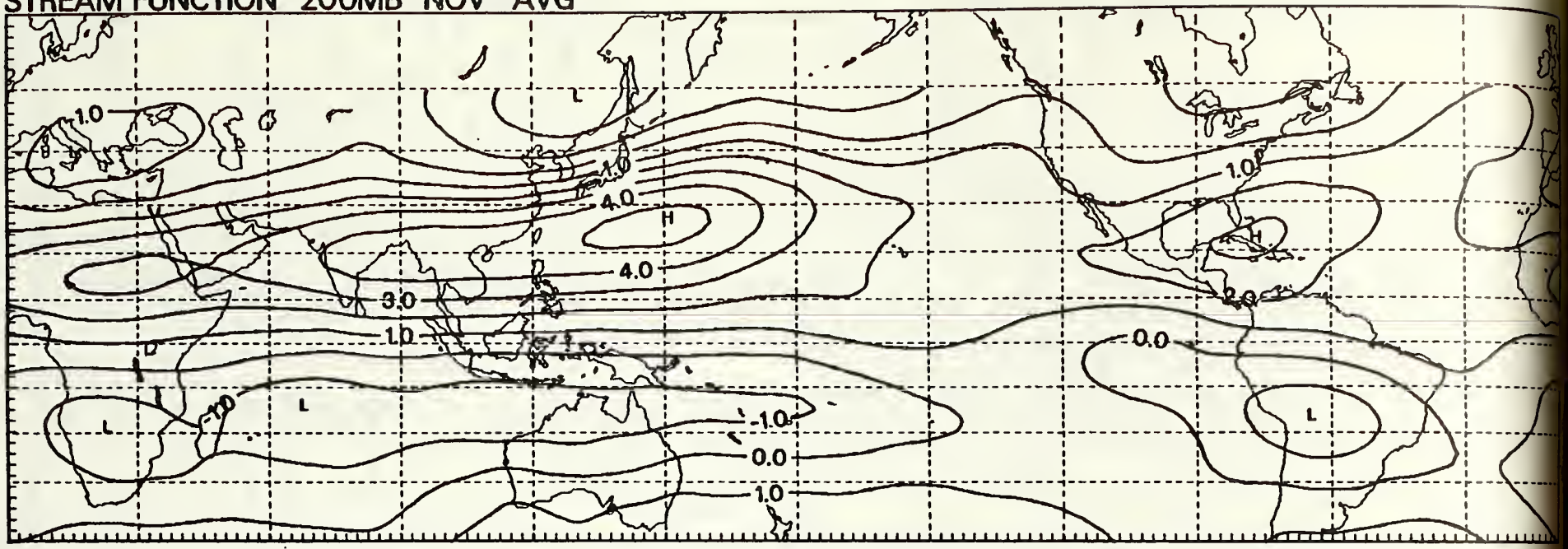


VELOCITY POTENTIAL 200MB WIN 1983



STREAM FUNCTION 200MB NOV AVG

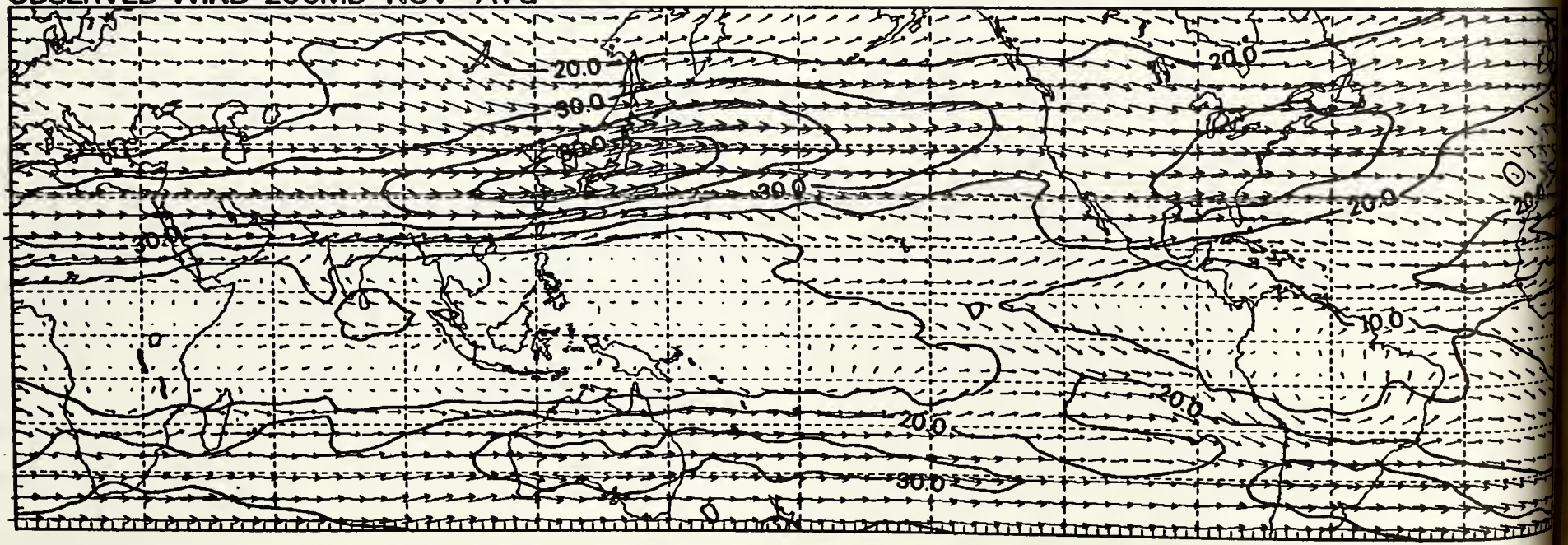
C1



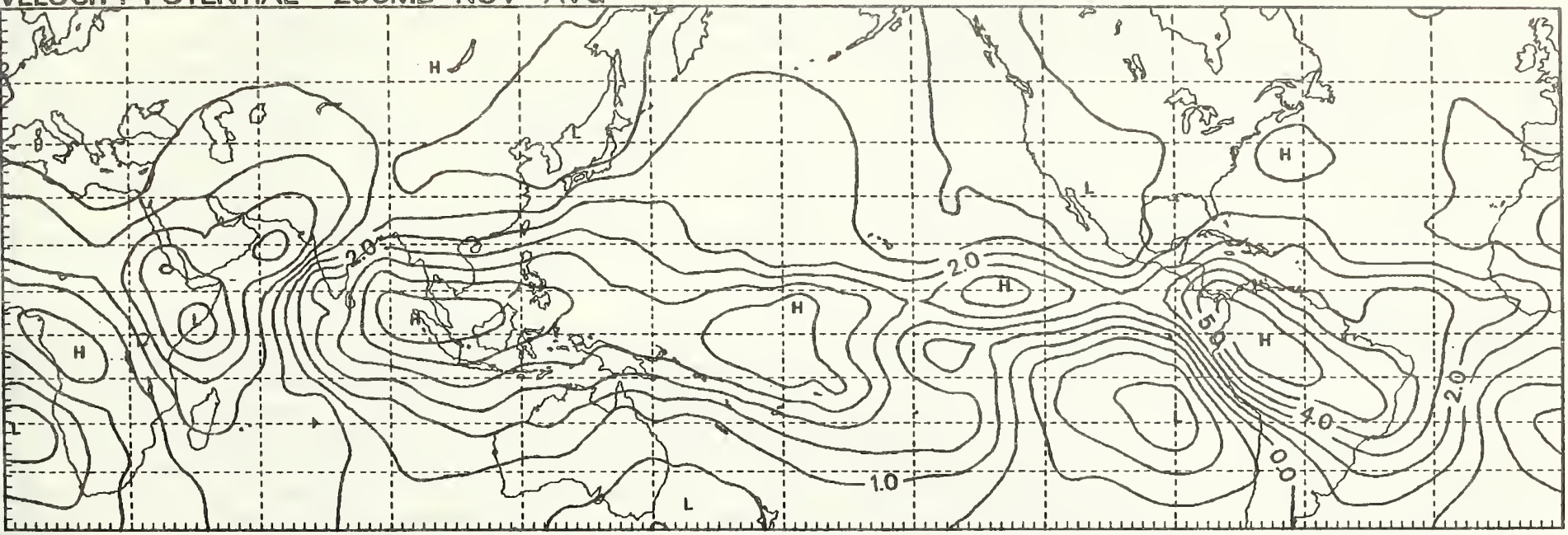
OBSERVED WIND 200MB NOV AVG

SCALE = 20

C2

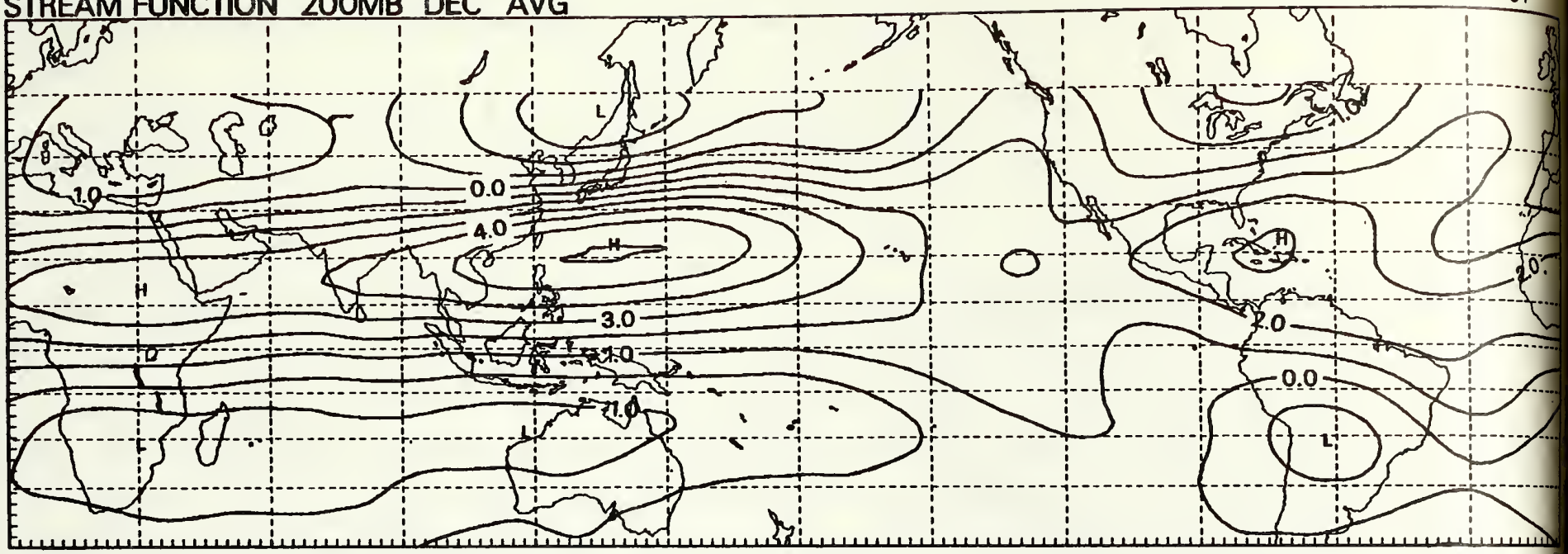


VELOCITY POTENTIAL 200MB NOV AVG C3



STREAM FUNCTION 200MB DEC AVG

C4



OBSERVED WIND 200MB DEC AVG

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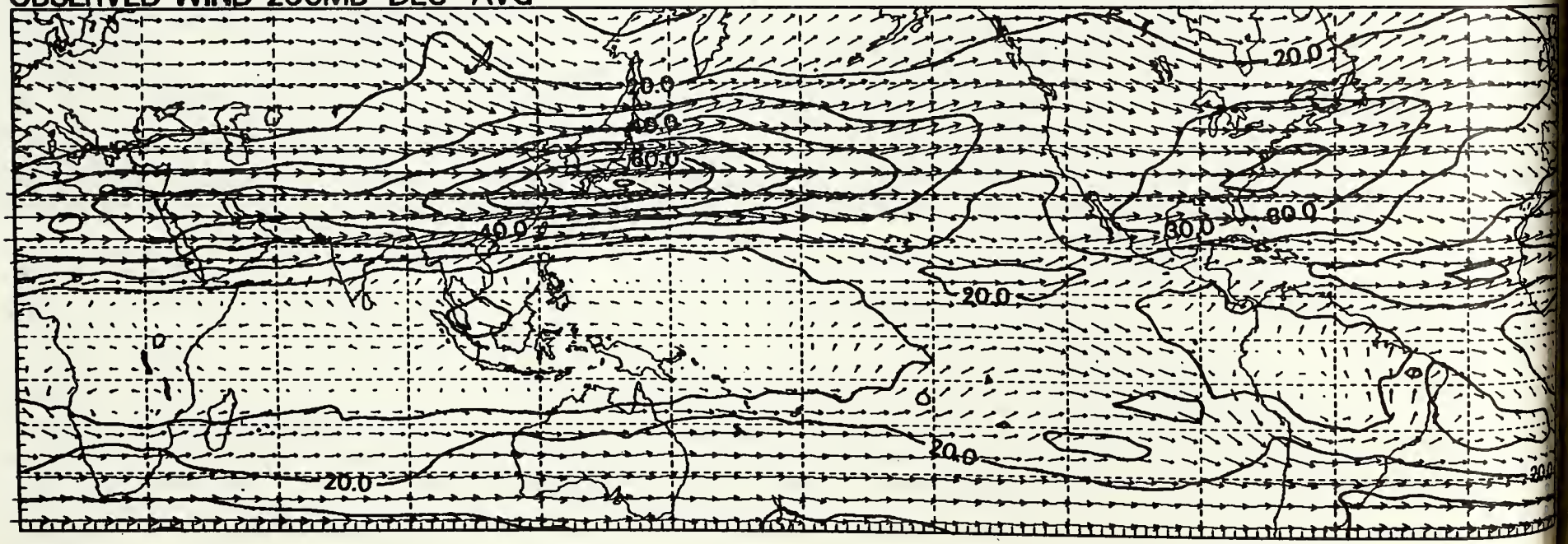
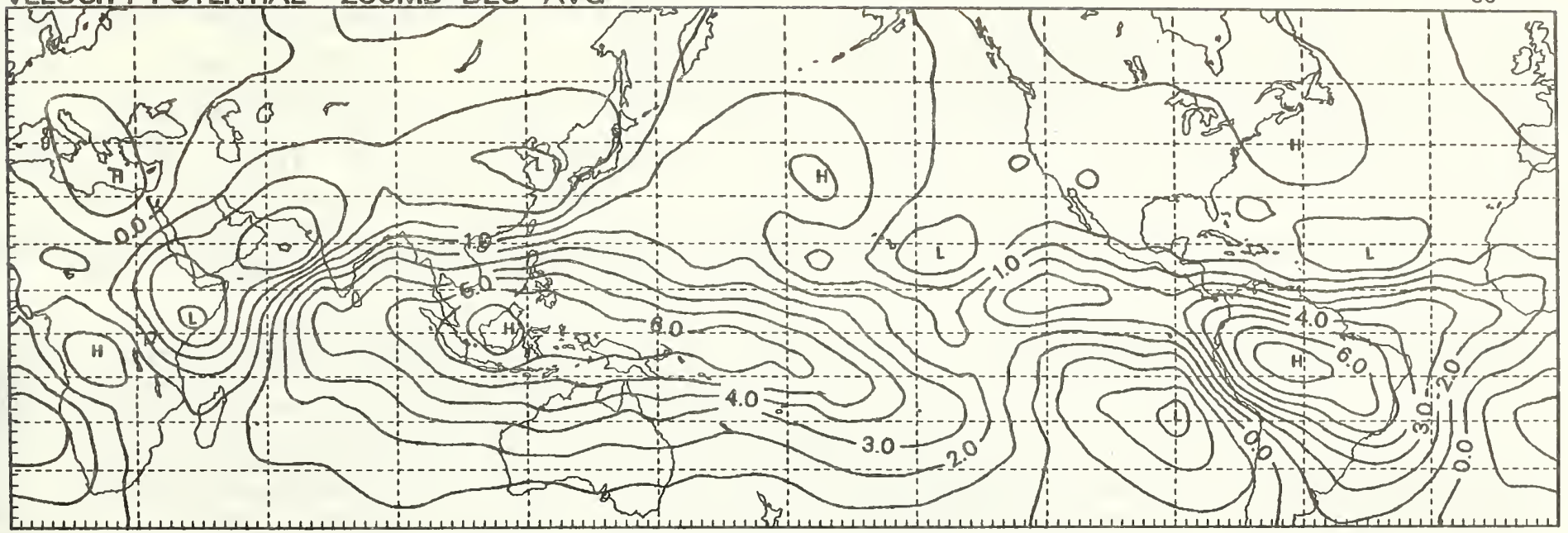
C5



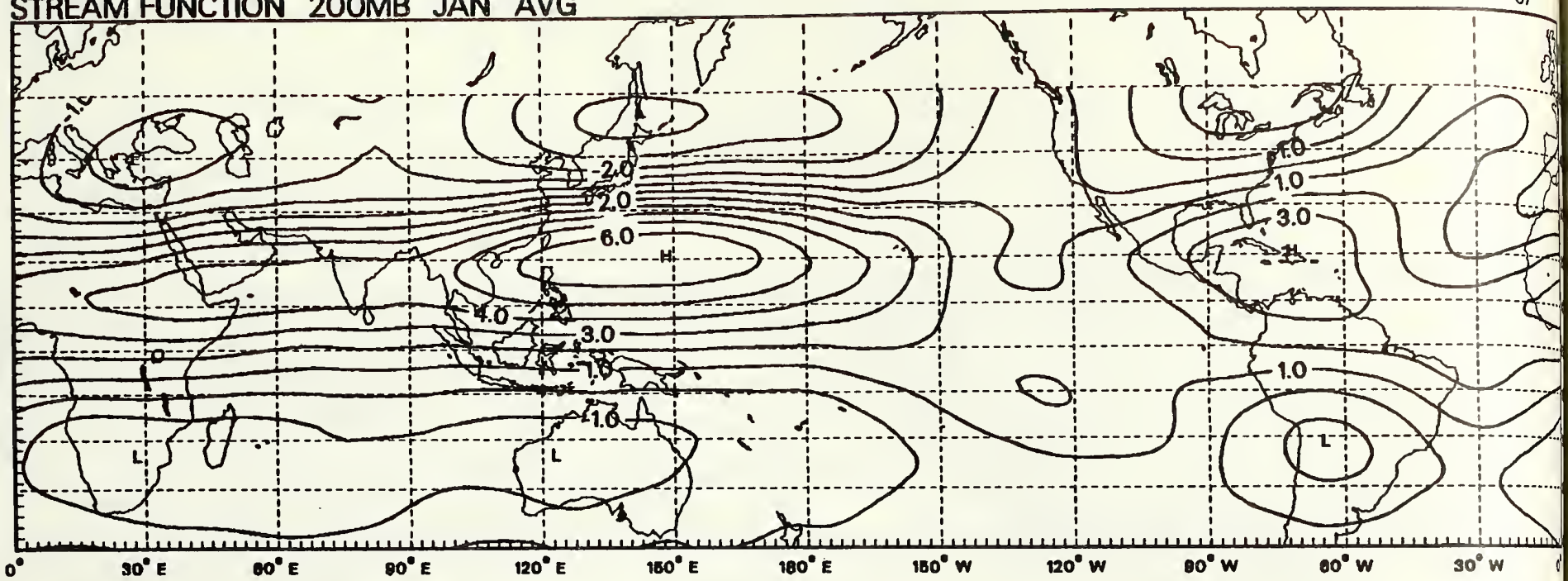
VELOCITY POTENTIAL 200MB DEC AVG

C6



C7

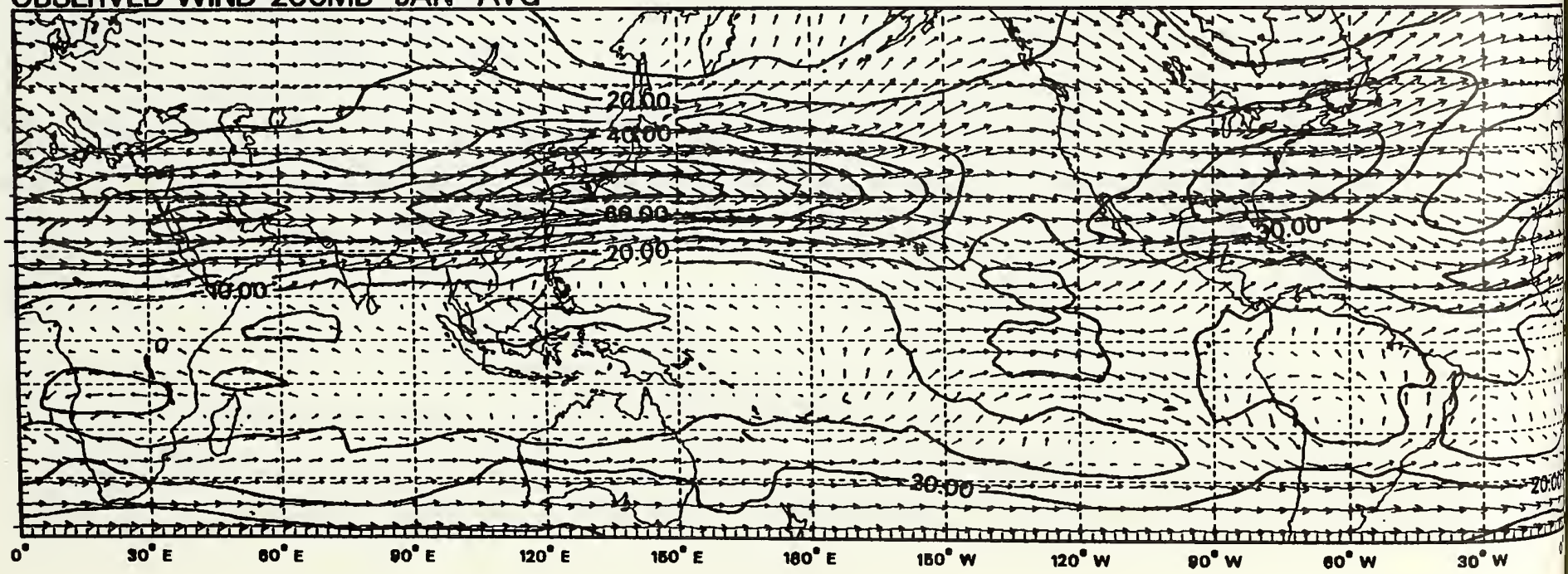
STREAM FUNCTION 200MB JAN AVG

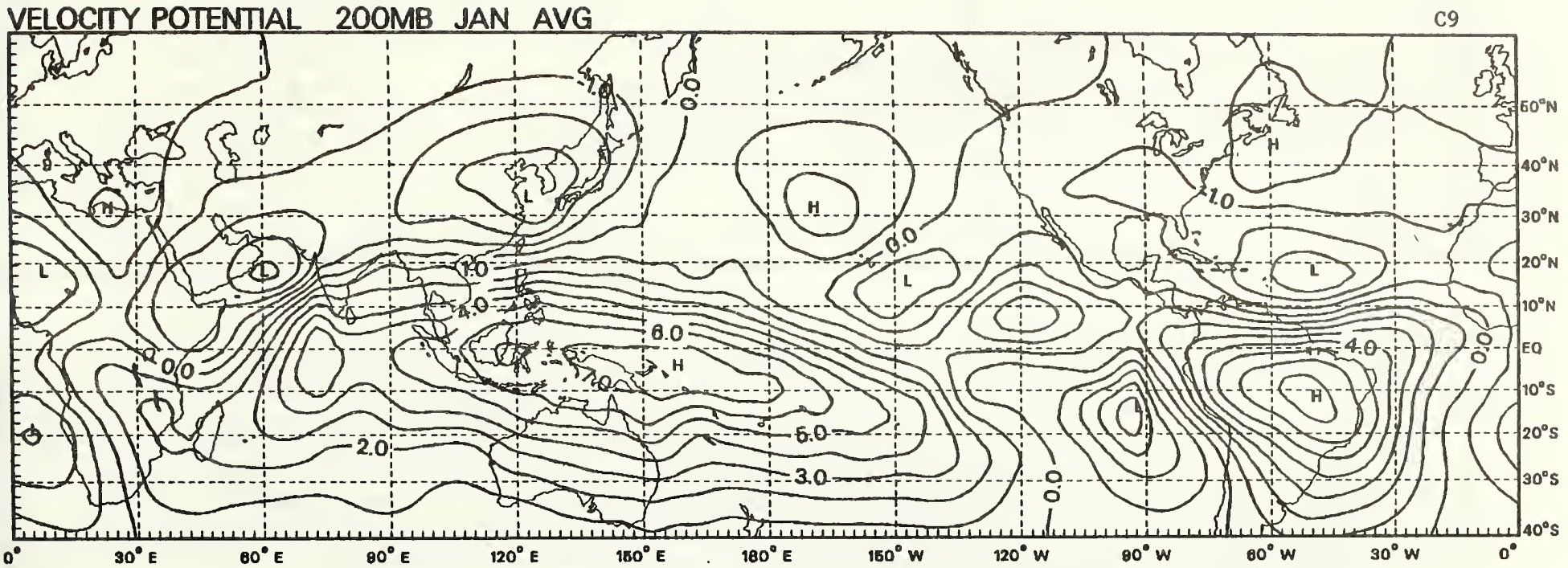


C8

OBSERVED WIND 200MB JAN AVG

SCALE = 20 —




VELOCITY POTENTIAL 200MB JAN AVG
C9
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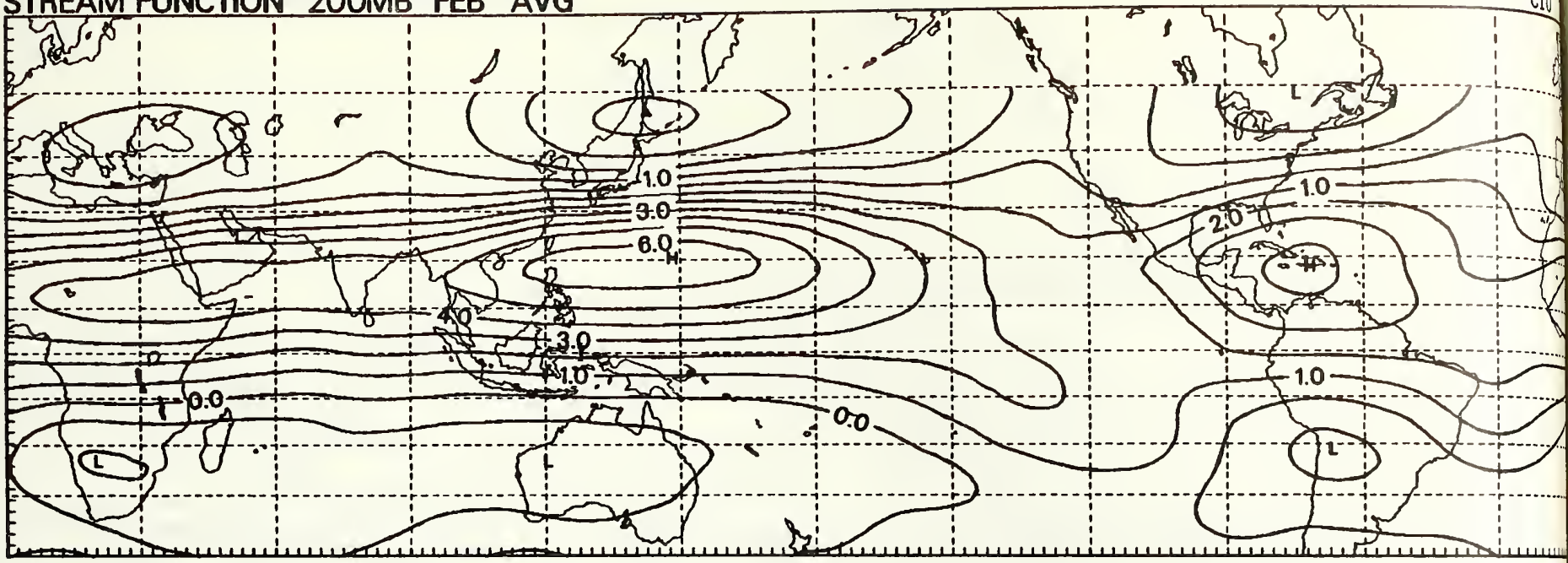
40°N
30°N
20°N
10°N
EQ
10°S
20°S
30°S
40°S
0°
30° E
60° E
90° E
120° E
150° E
180°
150° W
120° W
90° W
60° W
30° W
0°
H
L
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0

STREAM FUNCTION 200MB FEB AVG

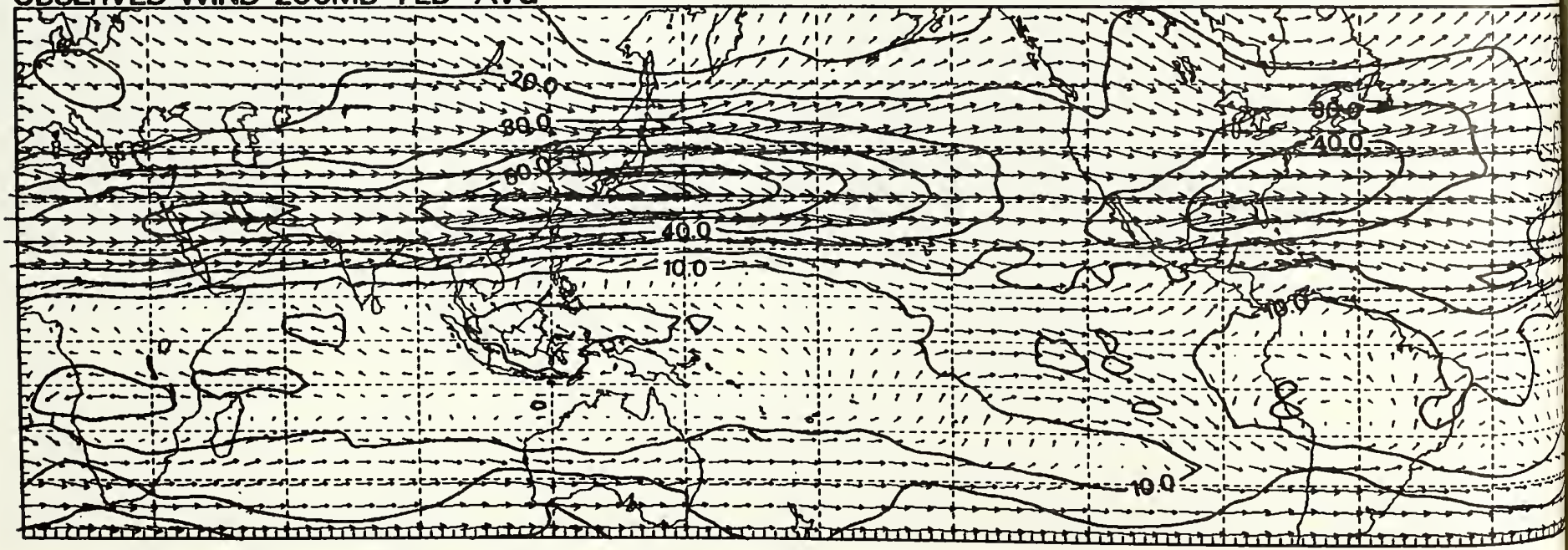
C10



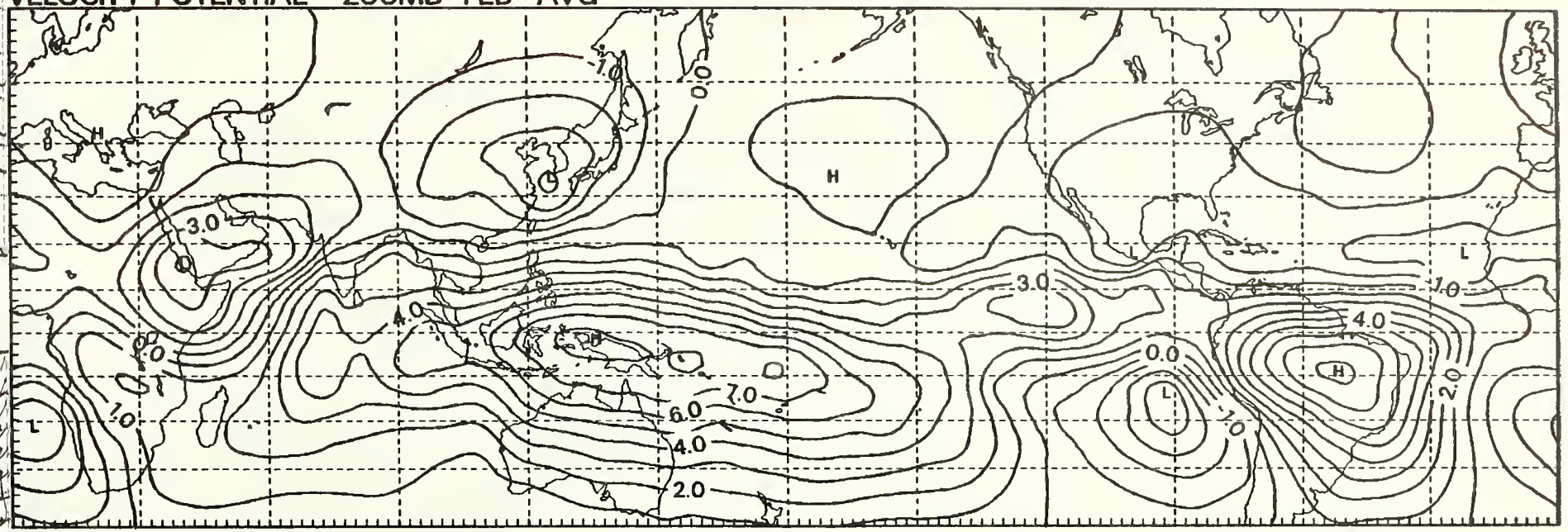
OBSERVED WIND 200MB FEB AVG

SCALE = 20 —

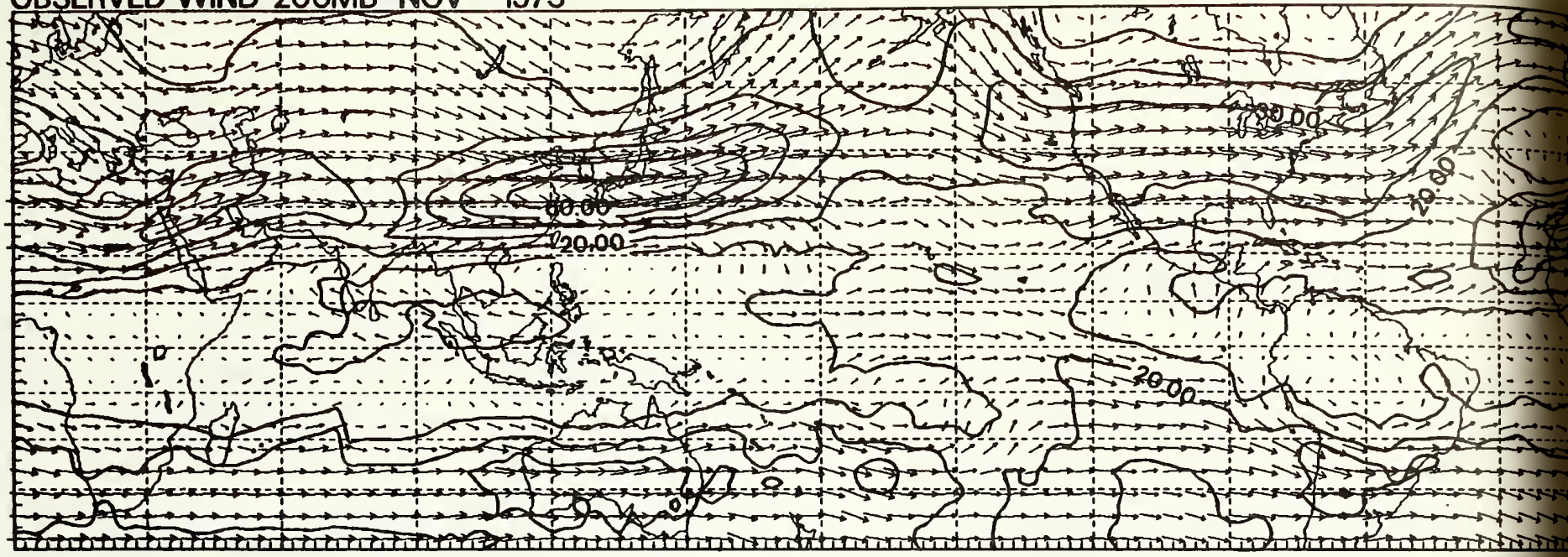
C11



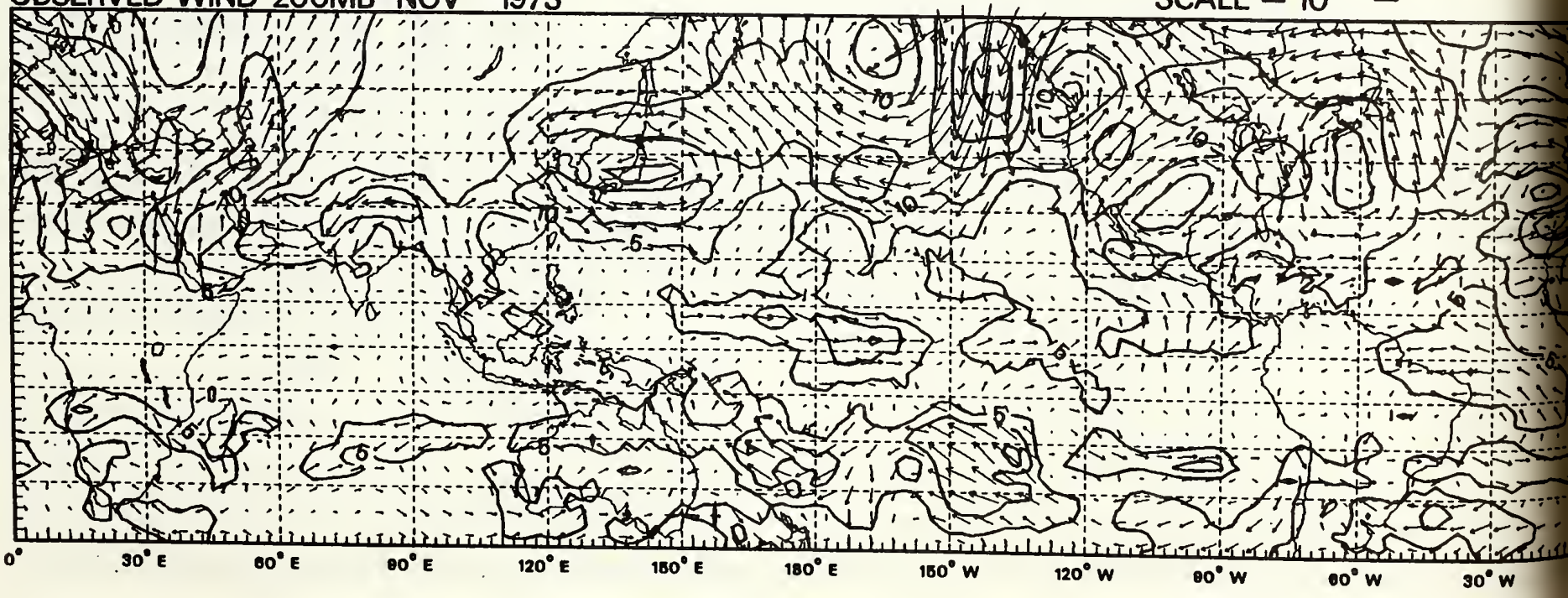
VELOCITY POTENTIAL 200MB FEB AVG C12



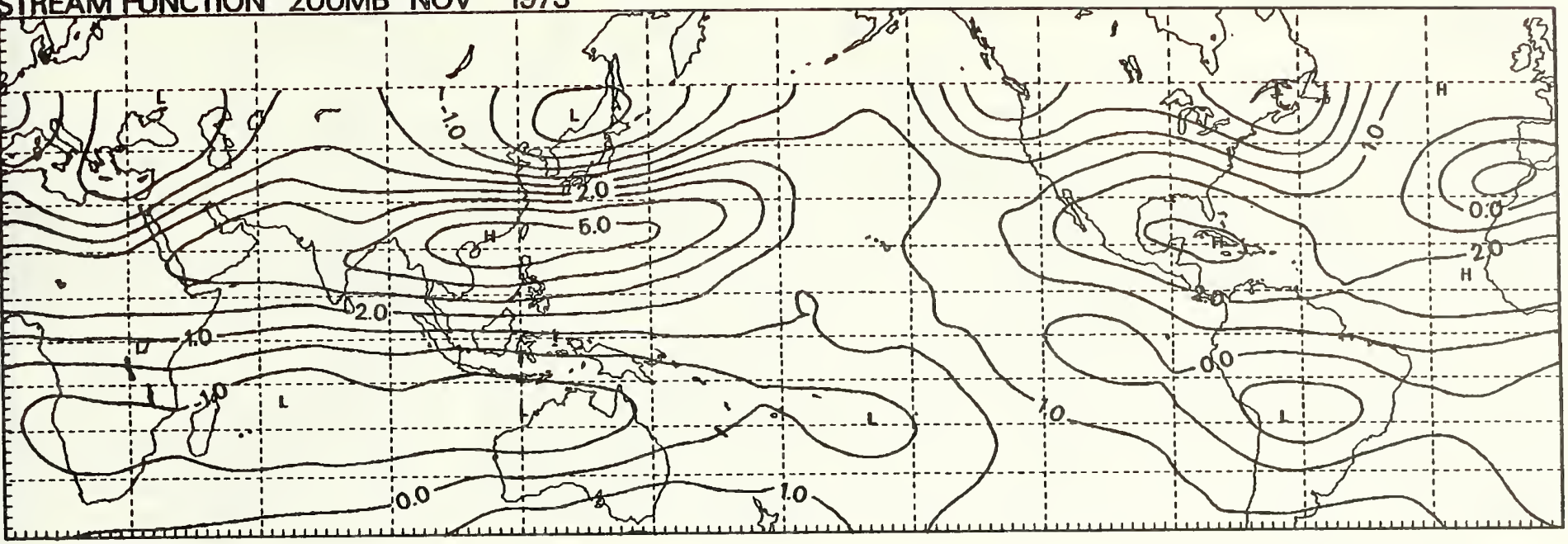
OBSERVED WIND 200MB NOV 1973 SCALE = 20



OBSERVED WIND 200MB NOV 1973 SCALE = 10



STREAM FUNCTION 200MB NOV 1973



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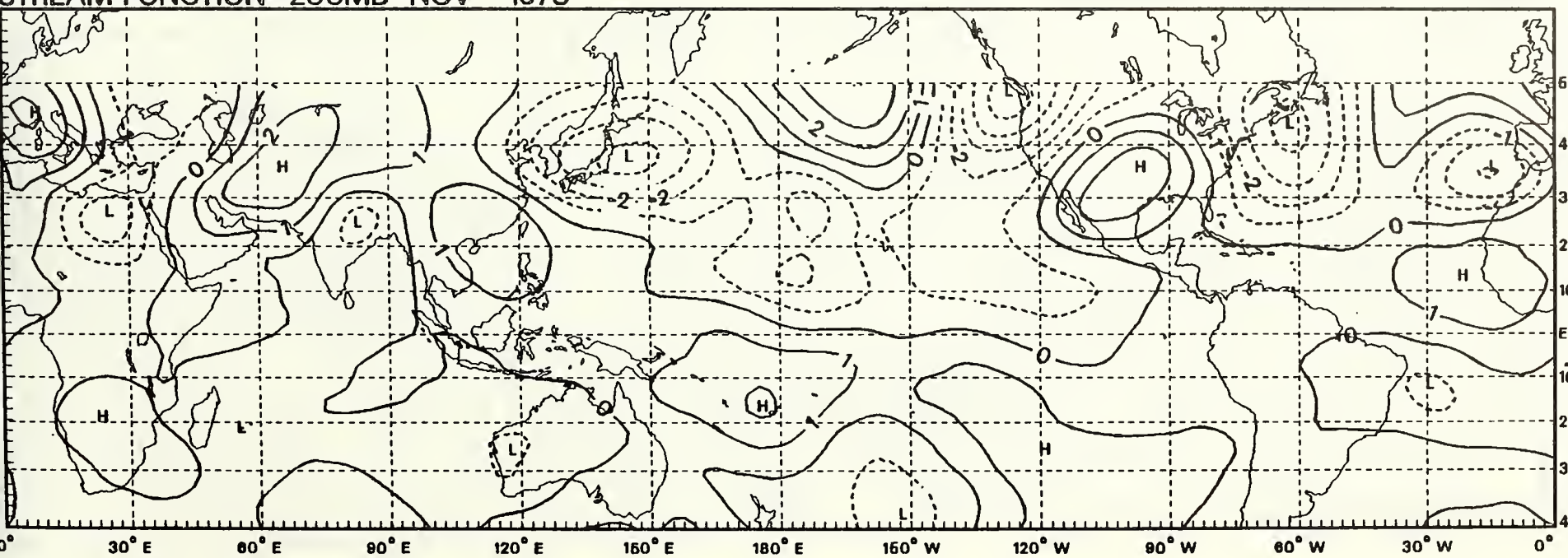

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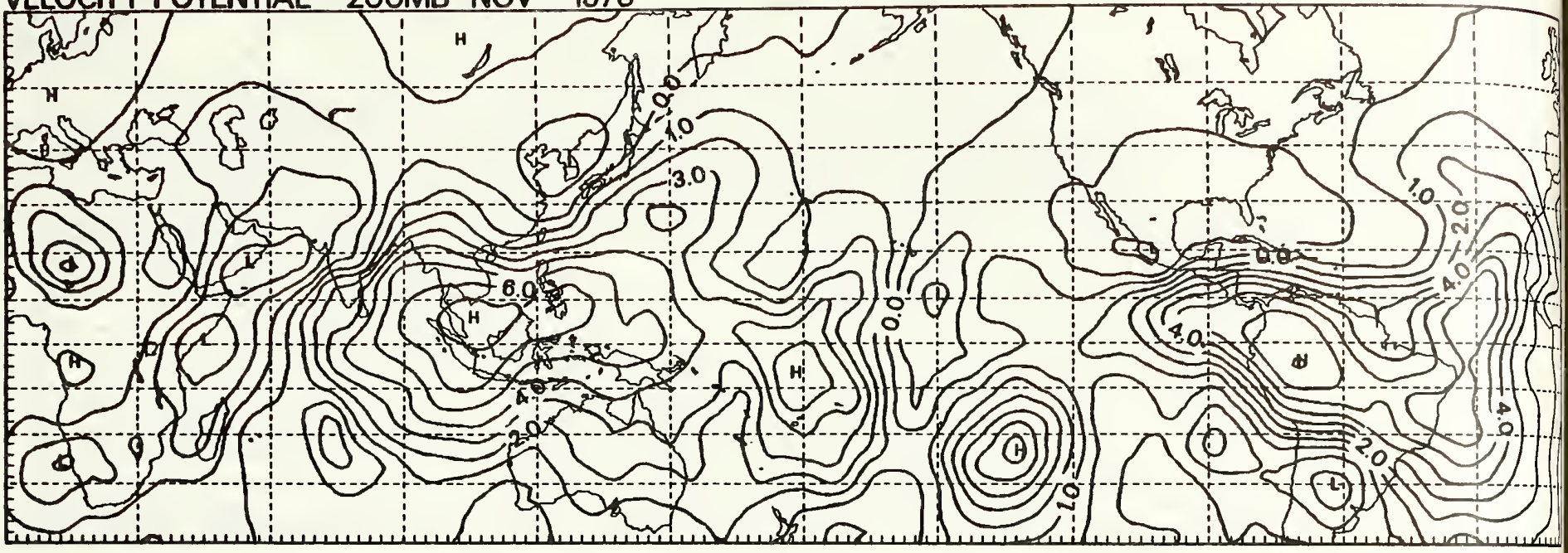
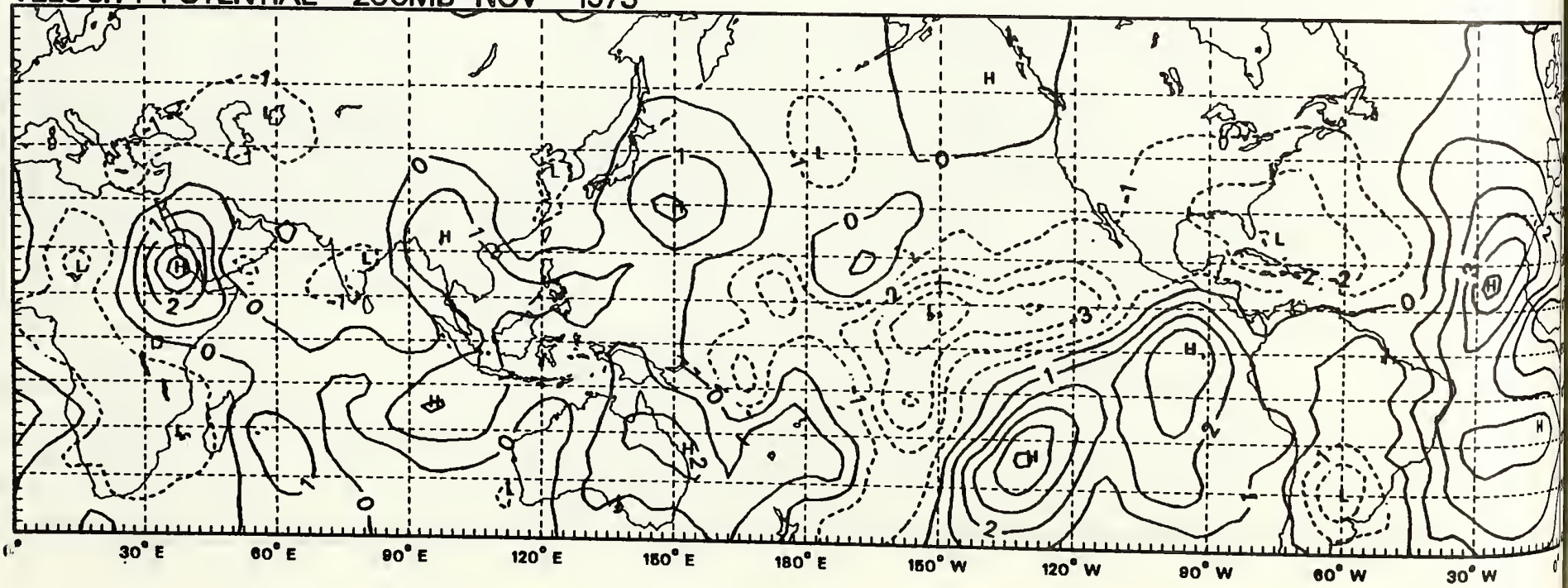
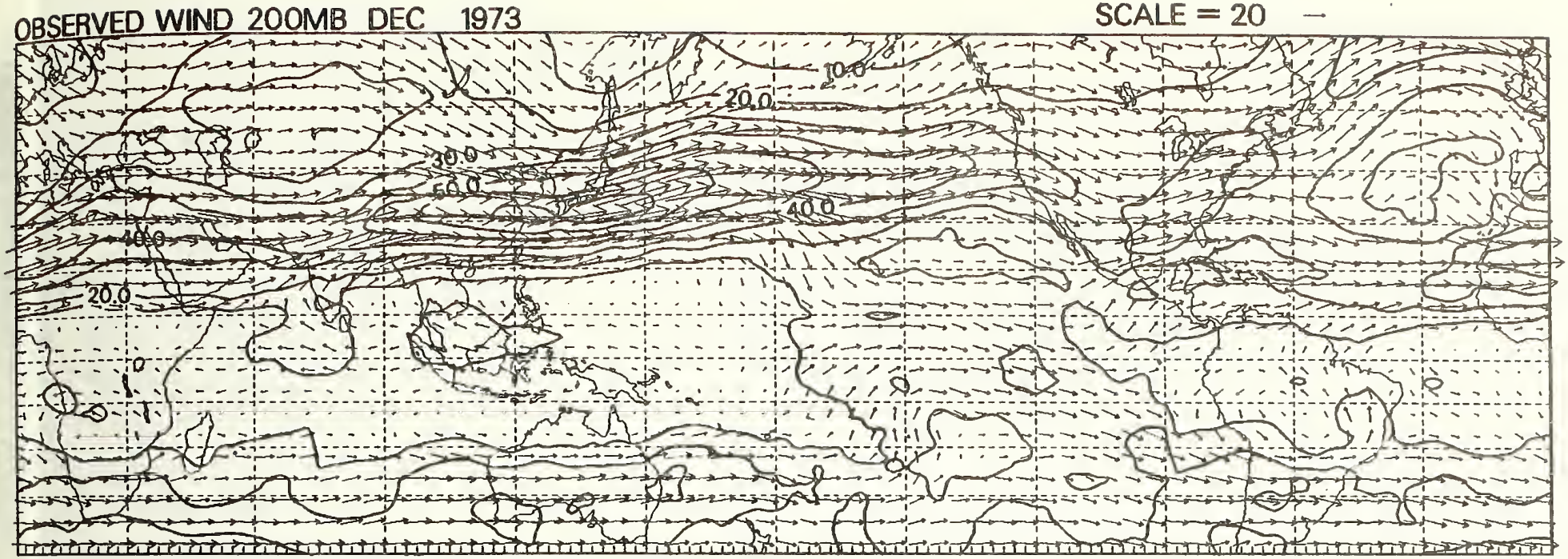


VELOCITY POTENTIAL 200MB NOV 1973

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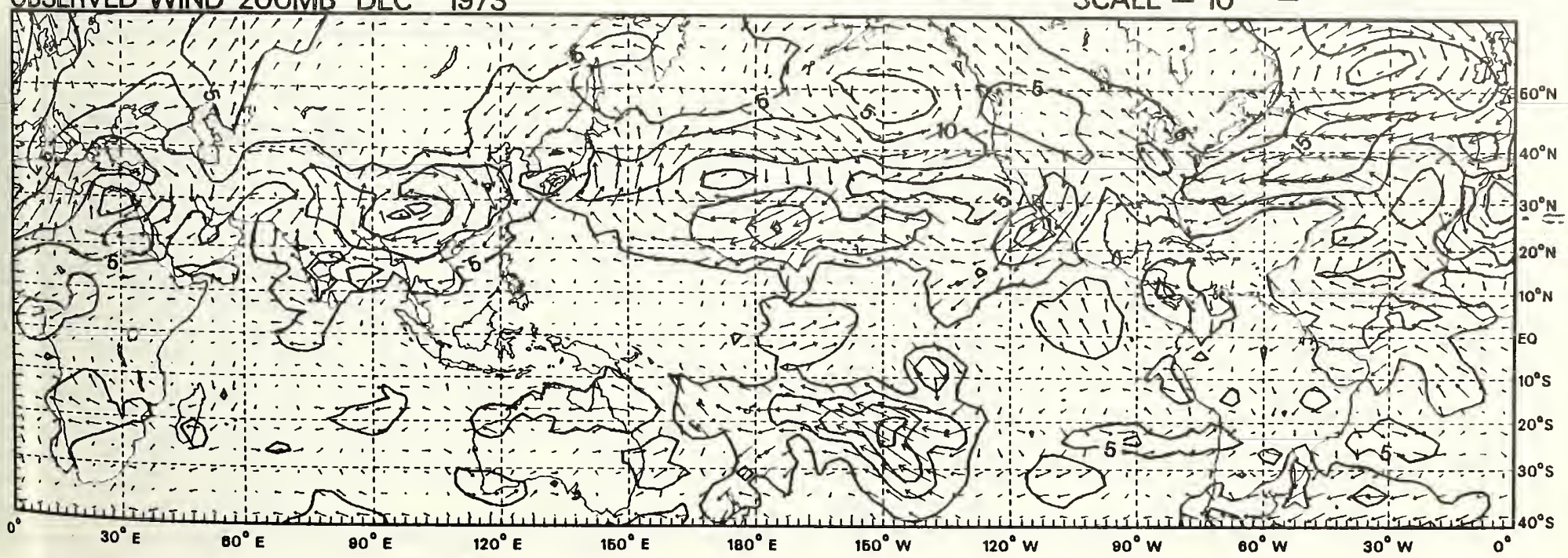
20.0


OBSERVED WIND 200MB DEC 1973
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20°S
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40°S
0°
30° E
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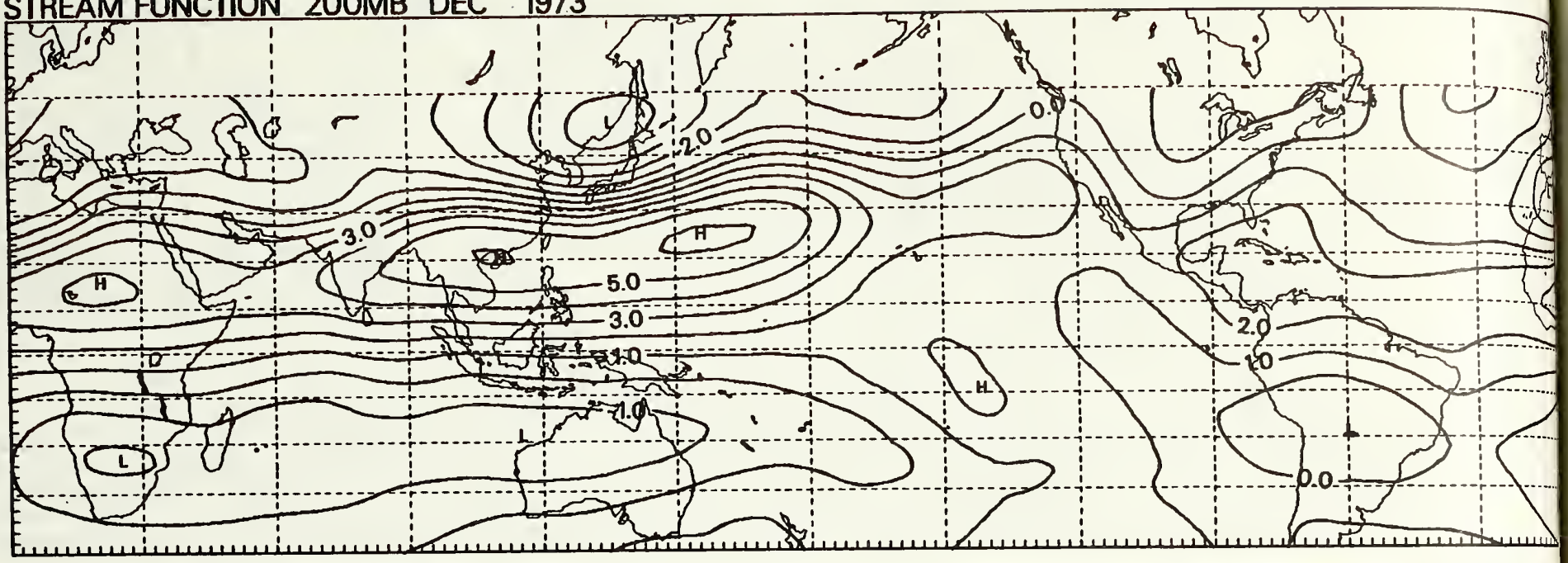
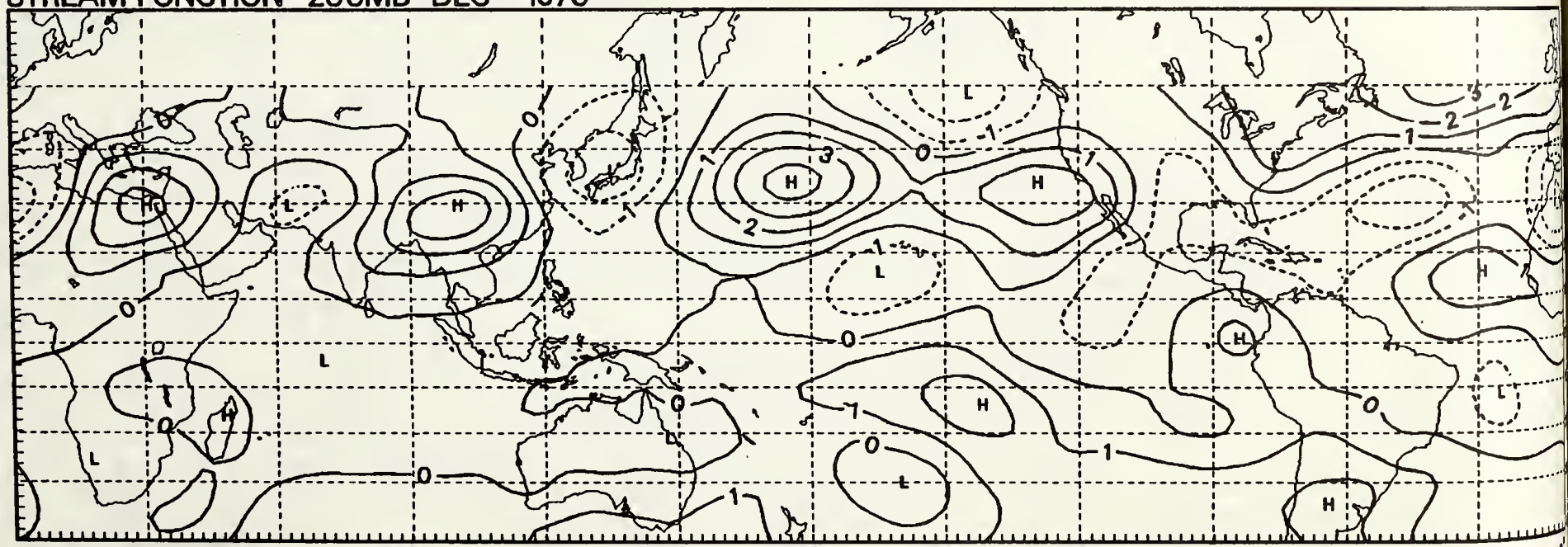
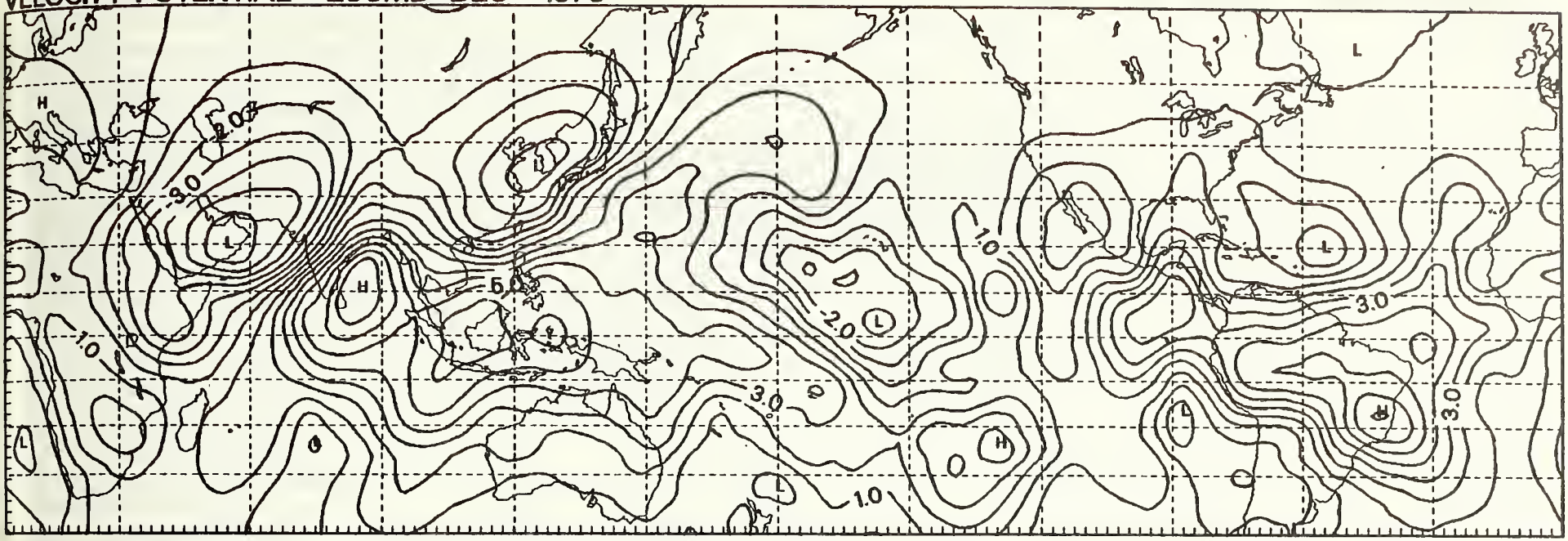
STREAM FUNCTION 200MB DEC 1973



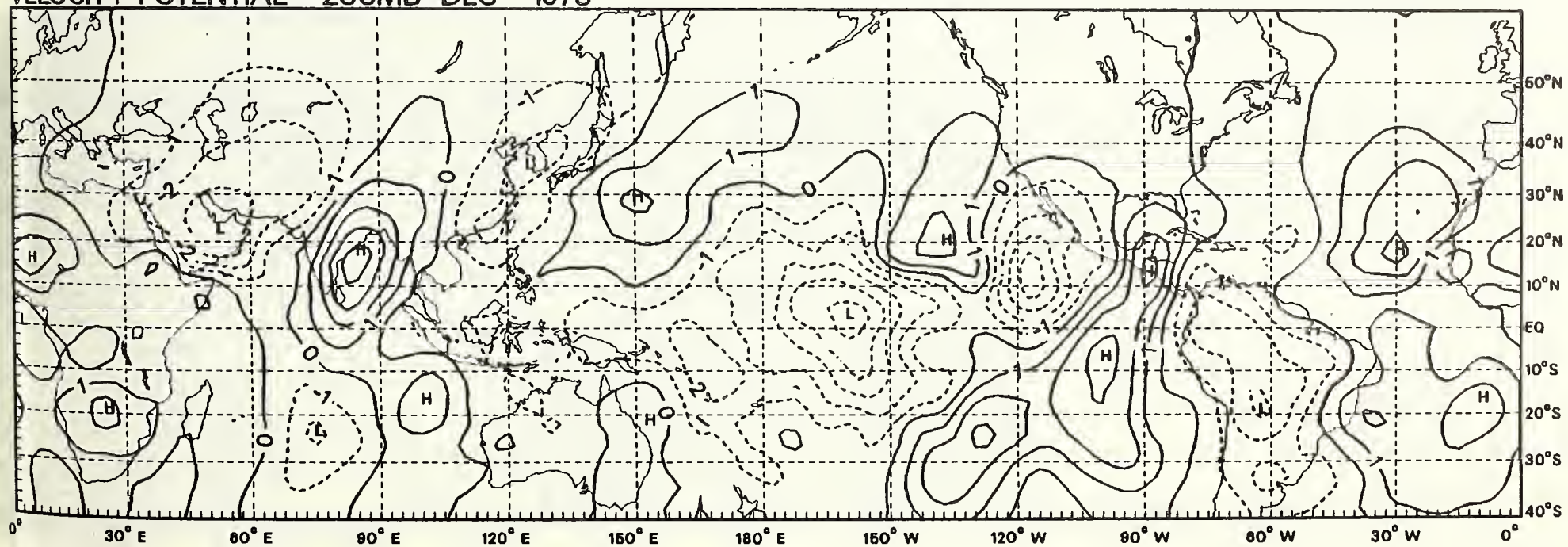
STREAM FUNCTION 200MB DEC 1973



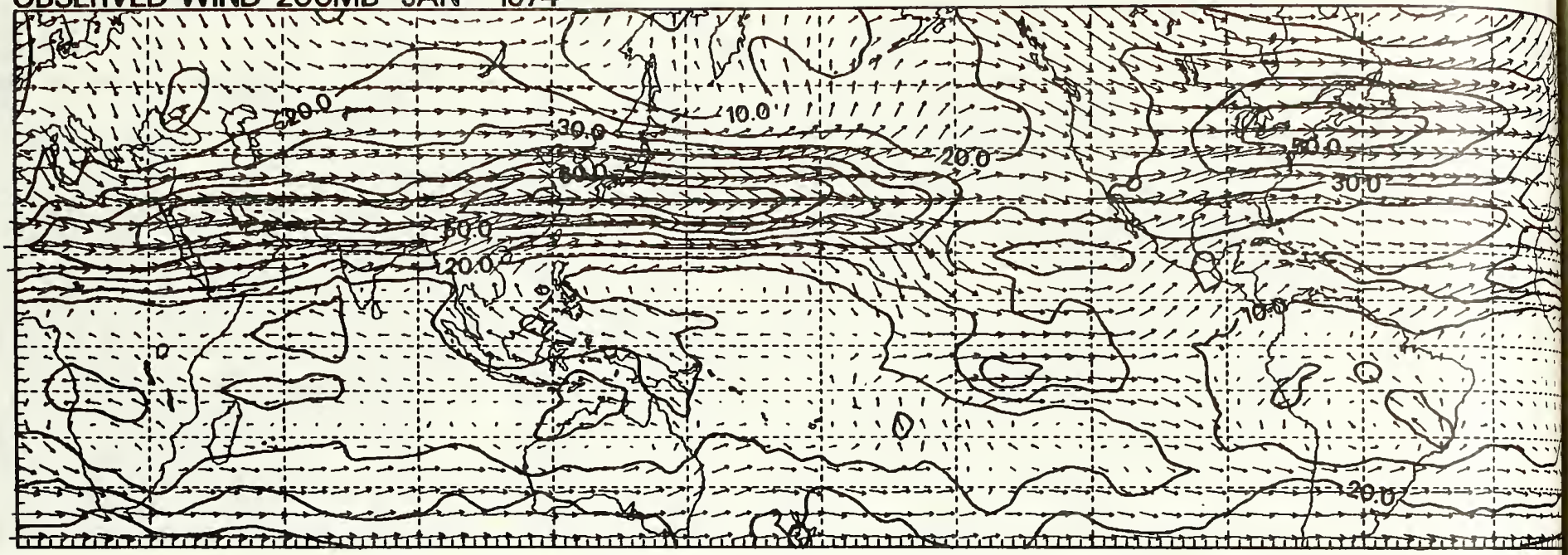
VELOCITY POTENTIAL 200MB DEC 1973



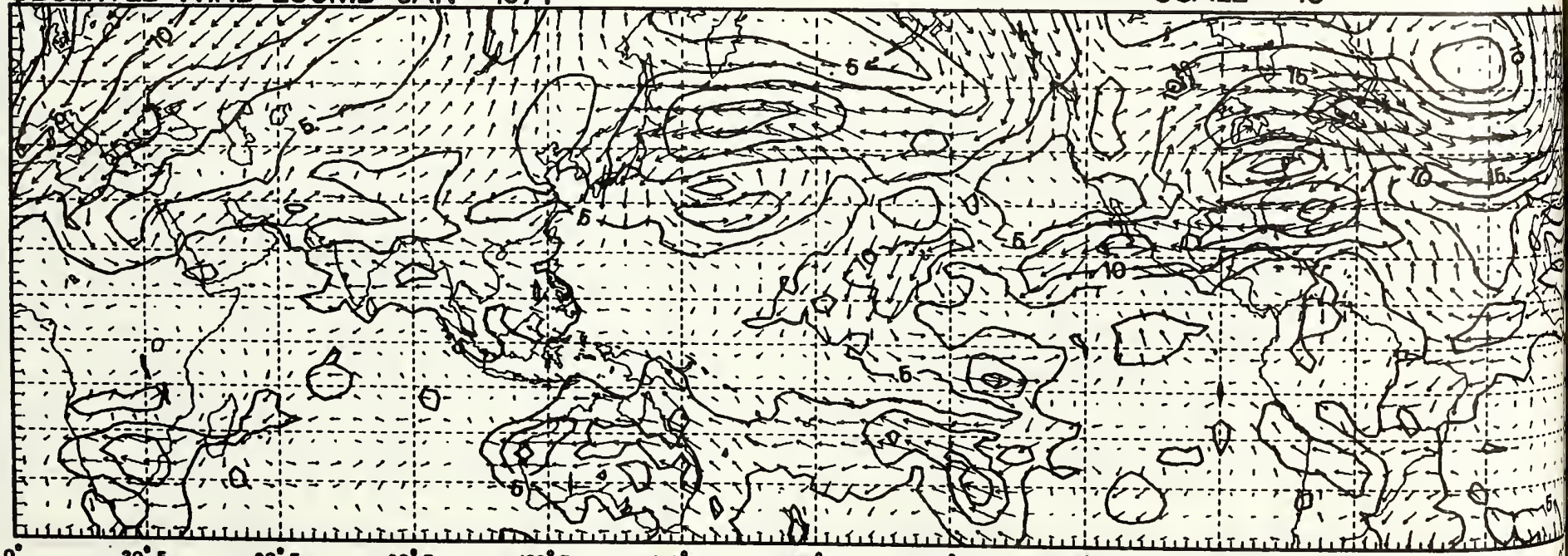
VELOCITY POTENTIAL 200MB DEC 1973



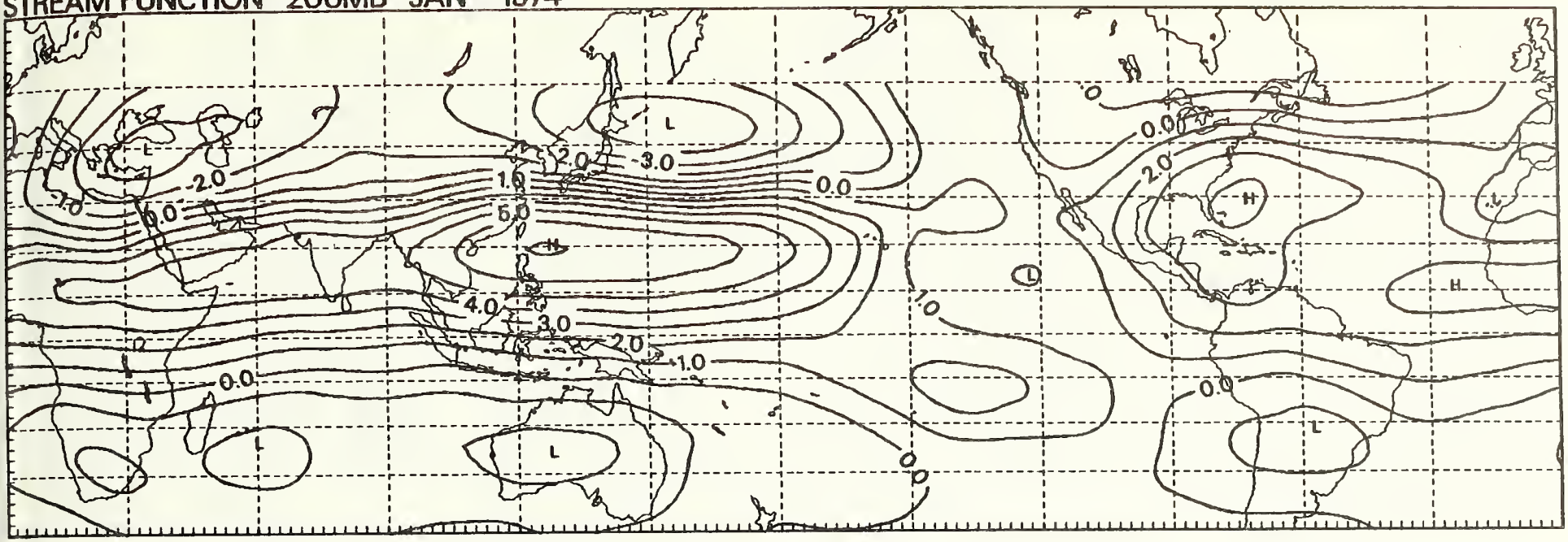
OBSERVED WIND 200MB JAN 1974 SCALE = 20



OBSERVED WIND 200MB JAN 1974 SCALE = 10



STREAM FUNCTION 200MB JAN 1974



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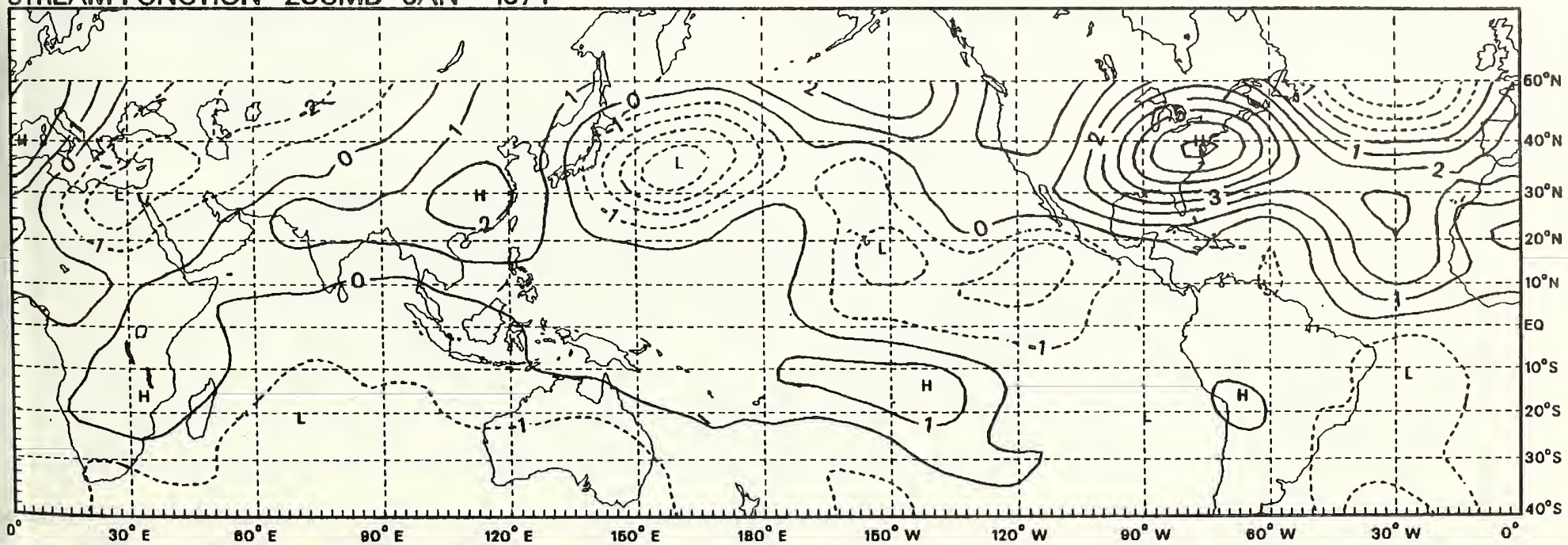
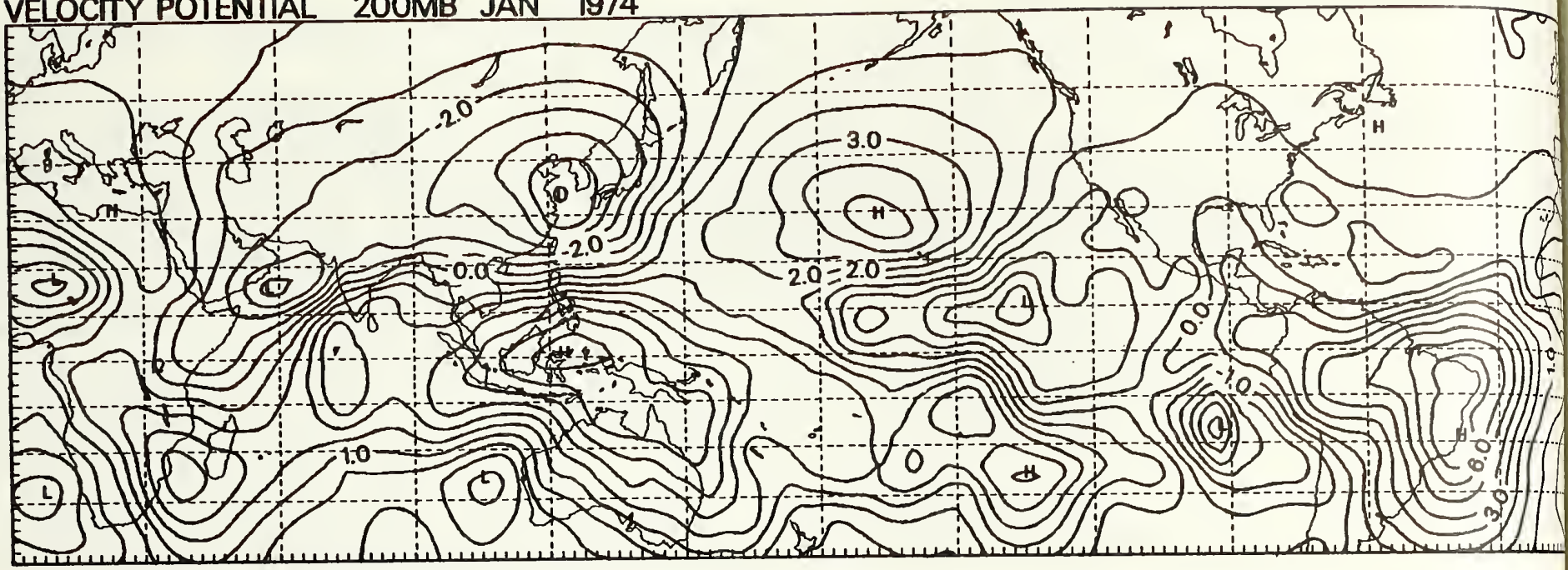
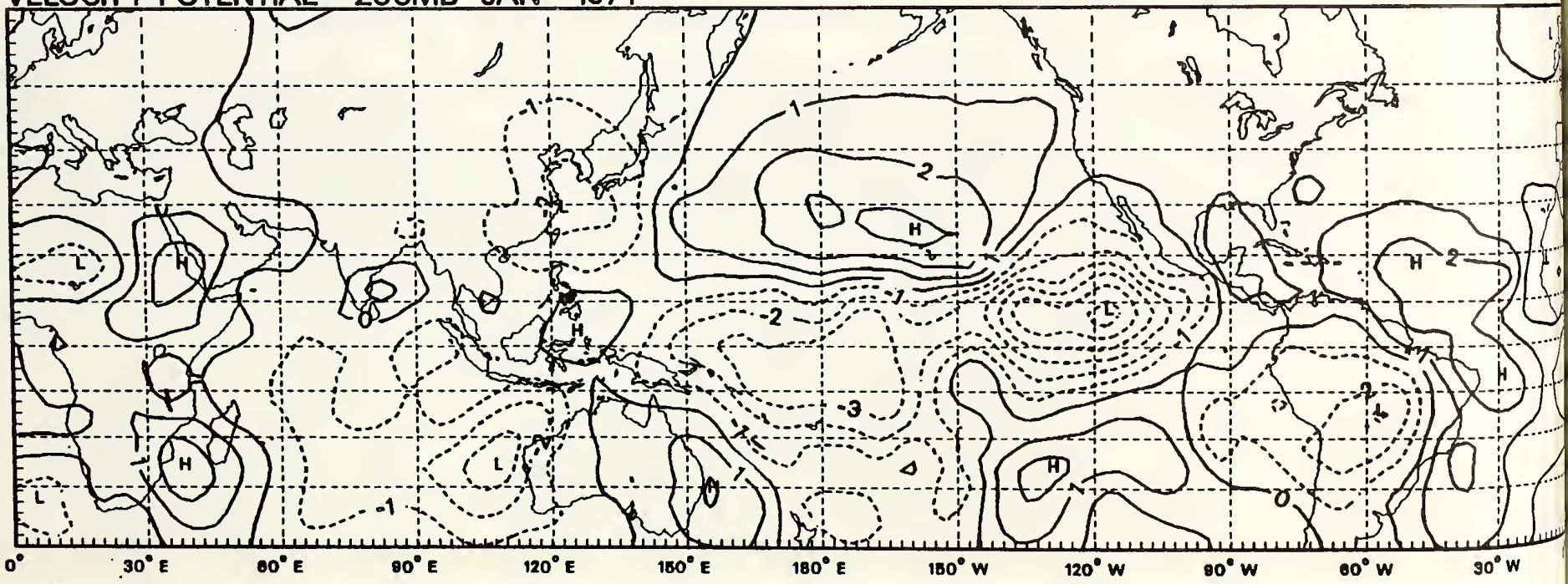
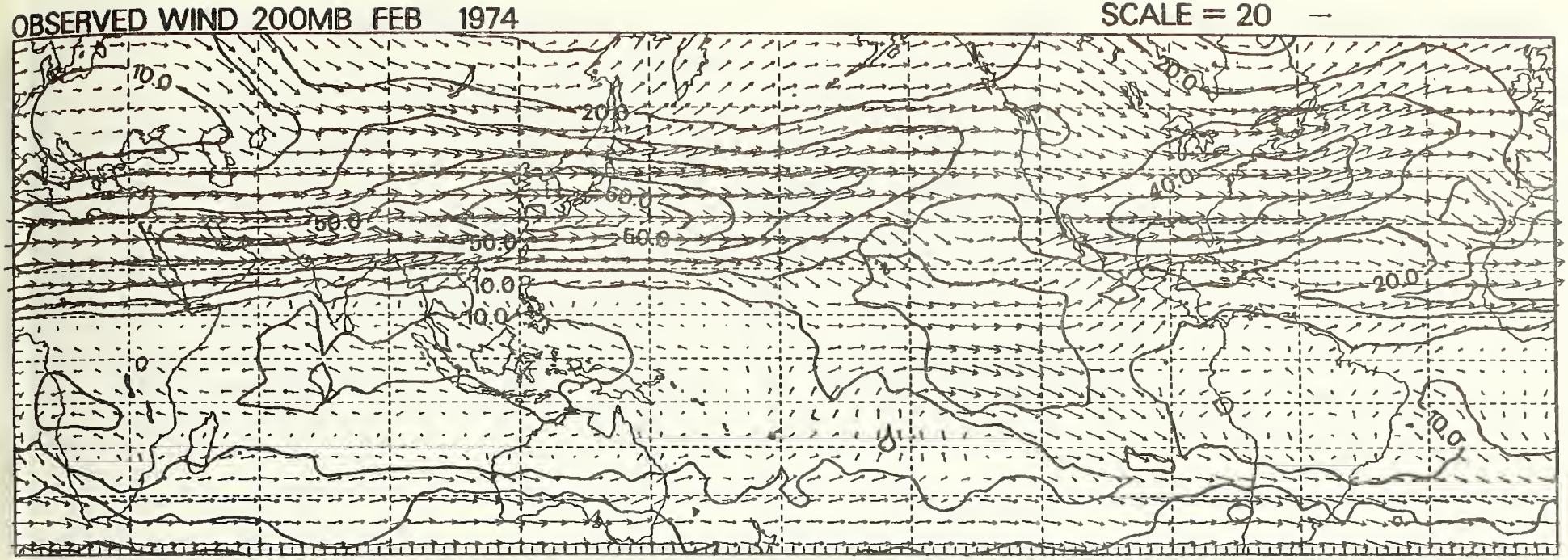


VELOCITY POTENTIAL 200MB JAN 1974



VELOCITY POTENTIAL 200MB JAN 1974

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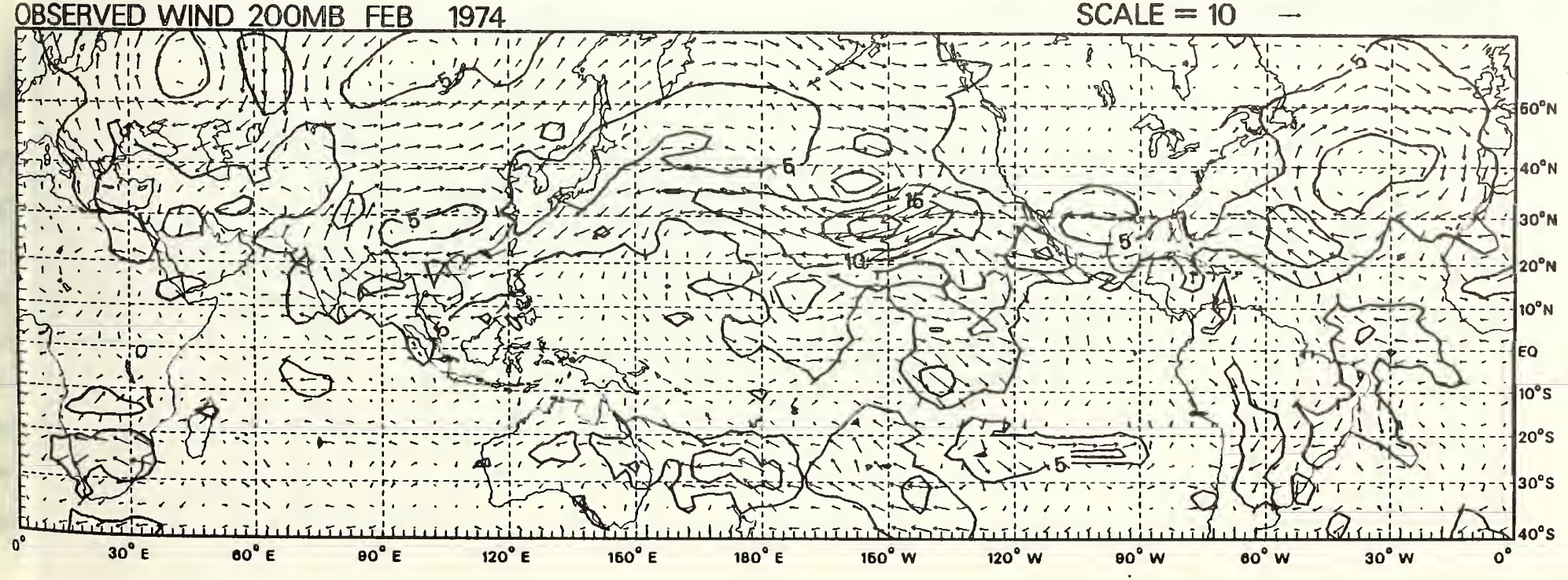
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60°N
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30°S
40°S
0°
30° E
60° E
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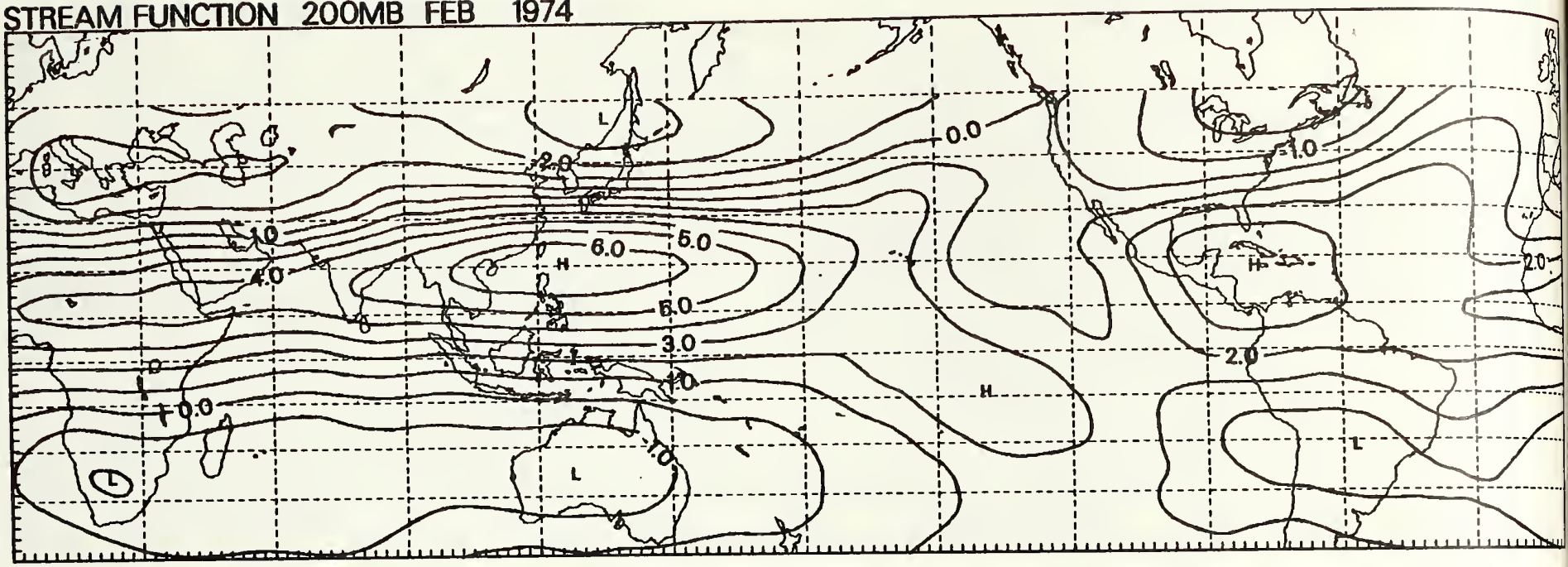
STREAM FUNCTION 200MB FEB 1974



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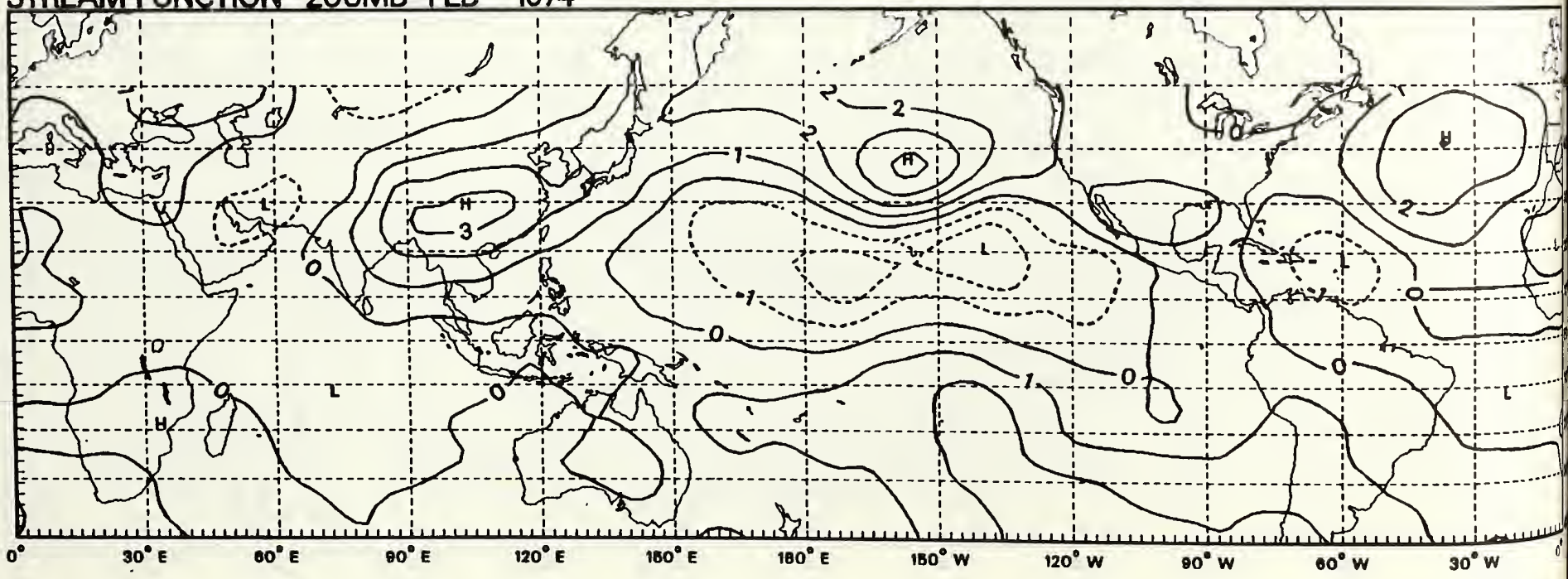
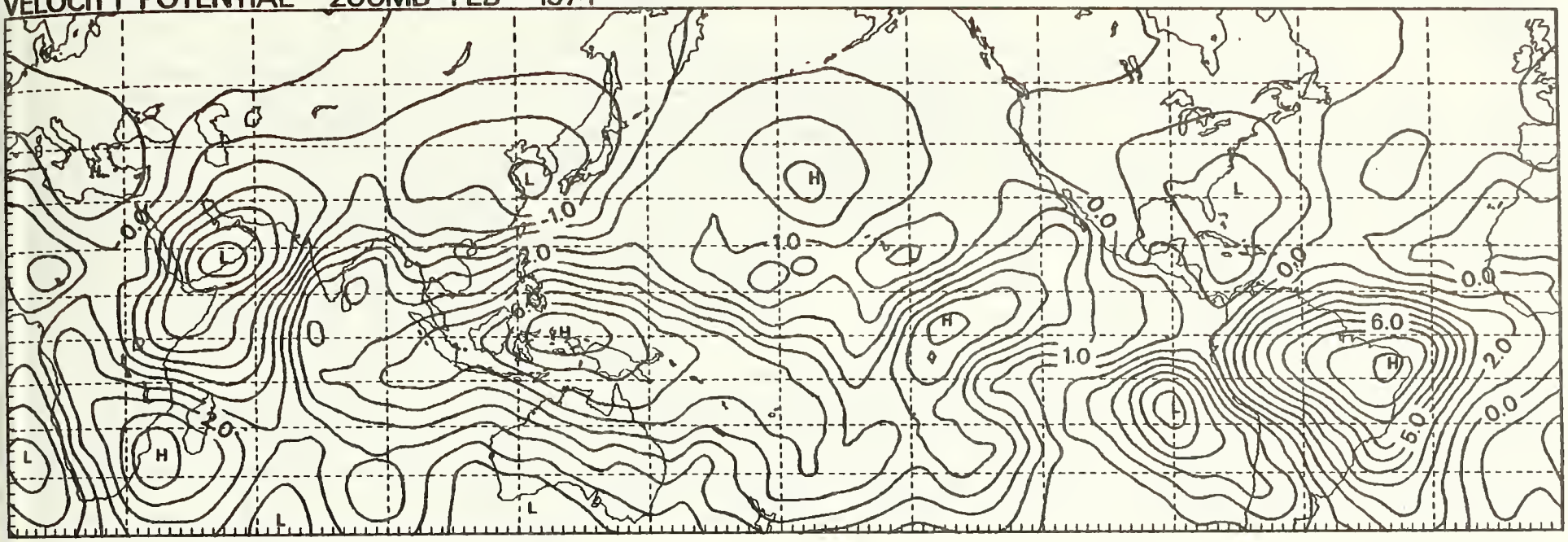


VELOCITY POTENTIAL 200MB FEB 1974



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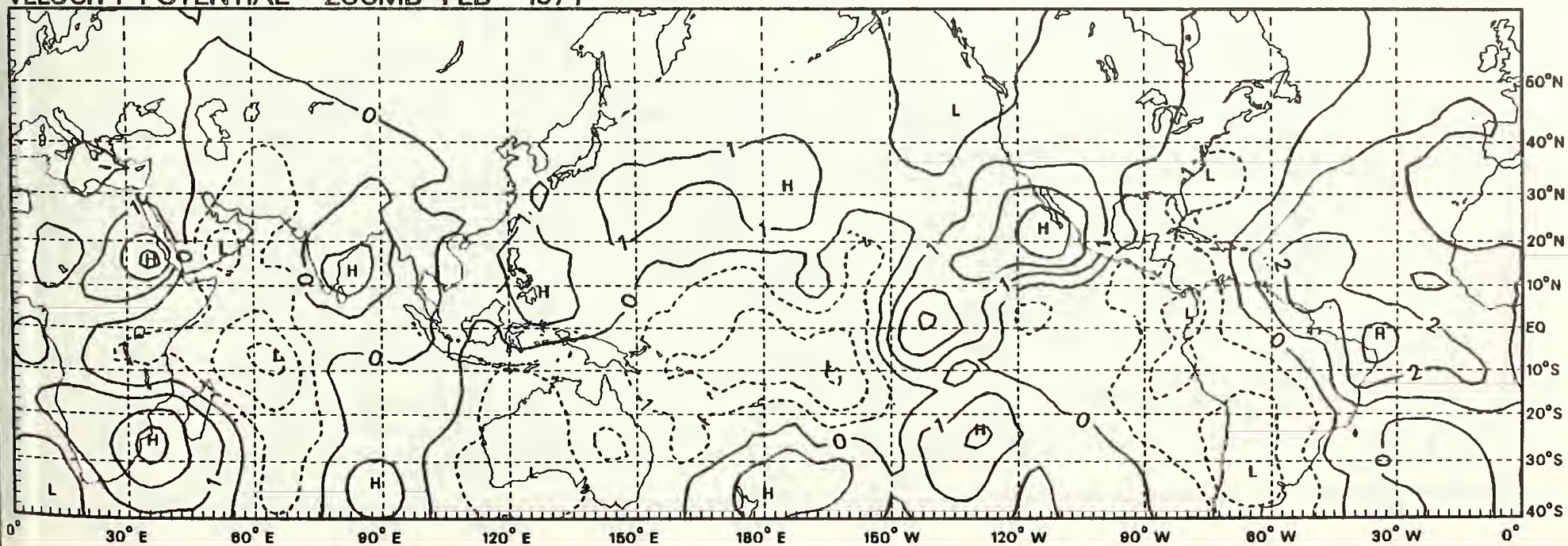
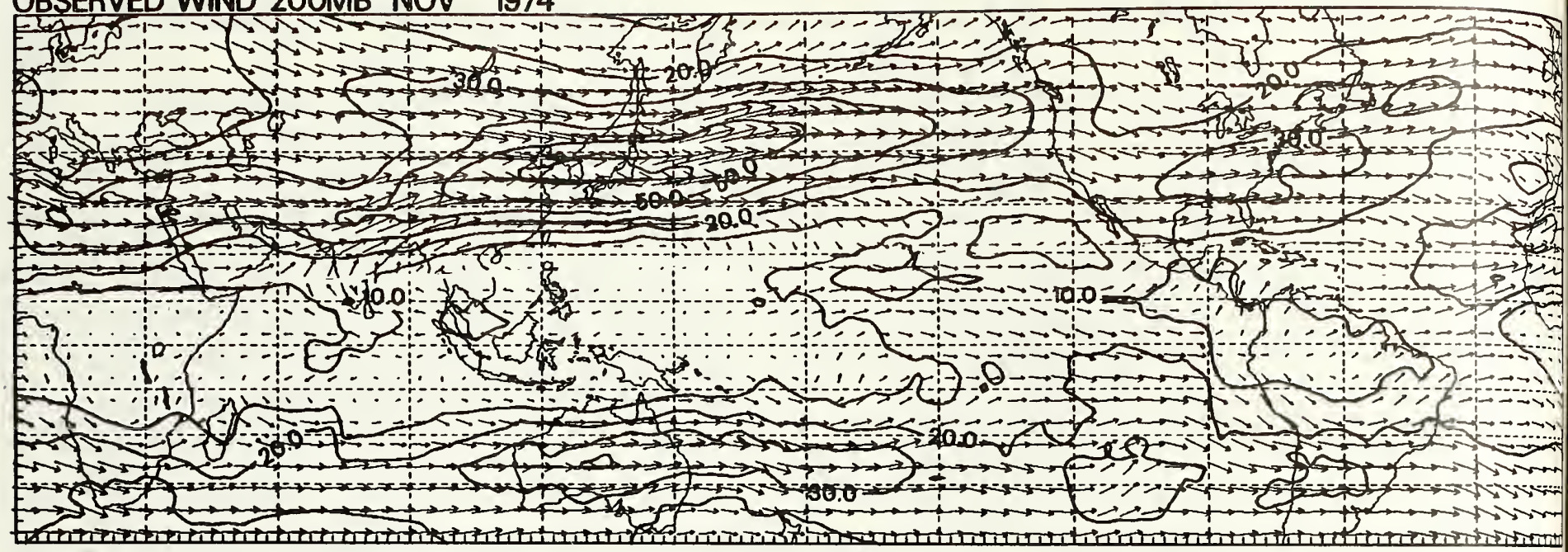


OBSERVED WIND 200MB NOV 1974 SCALE = 20



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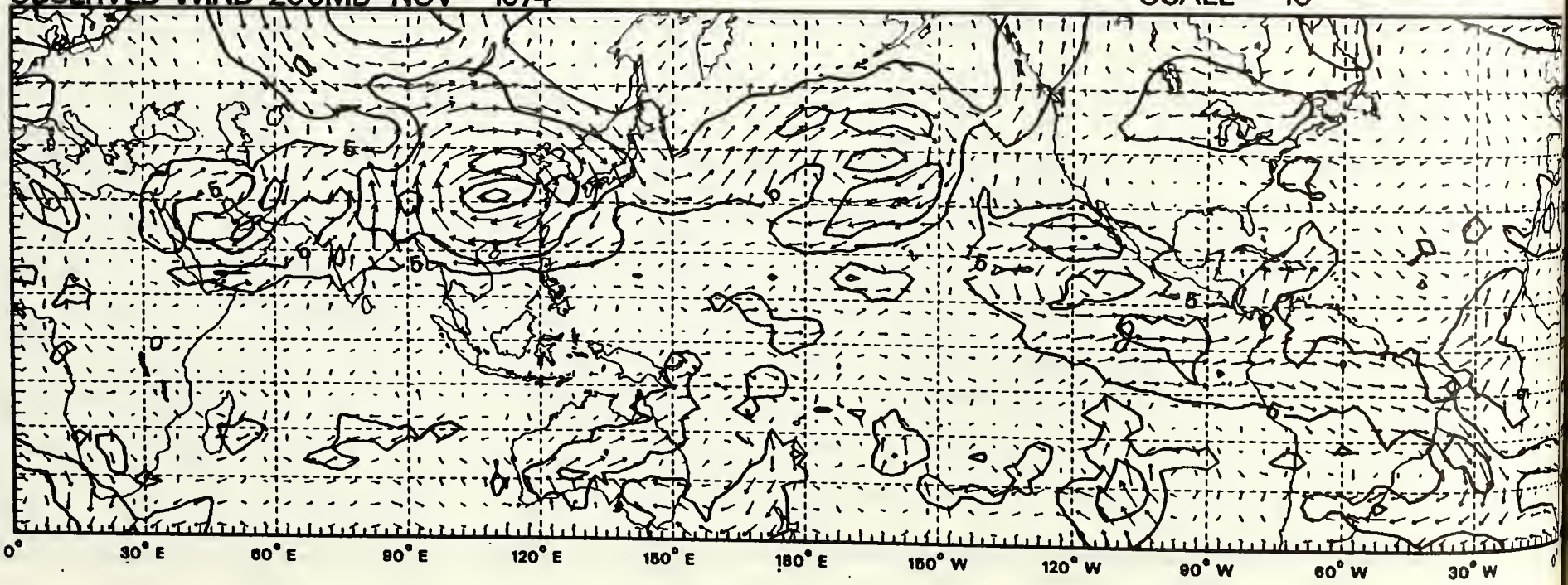
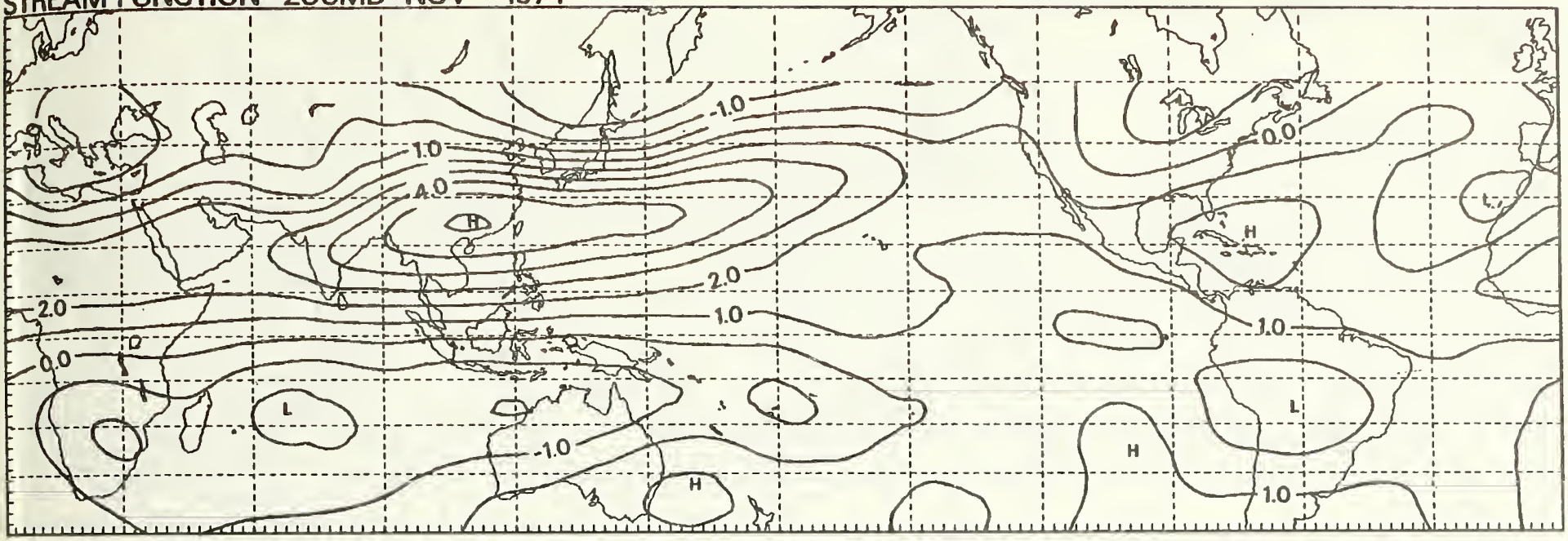
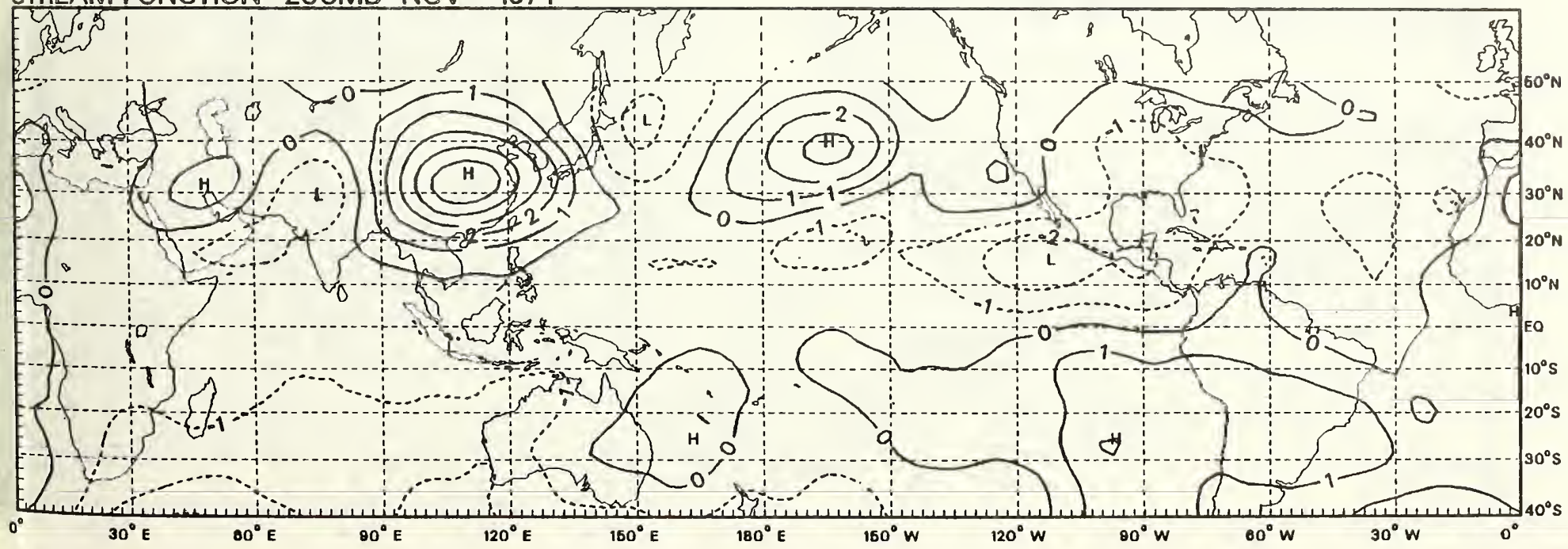


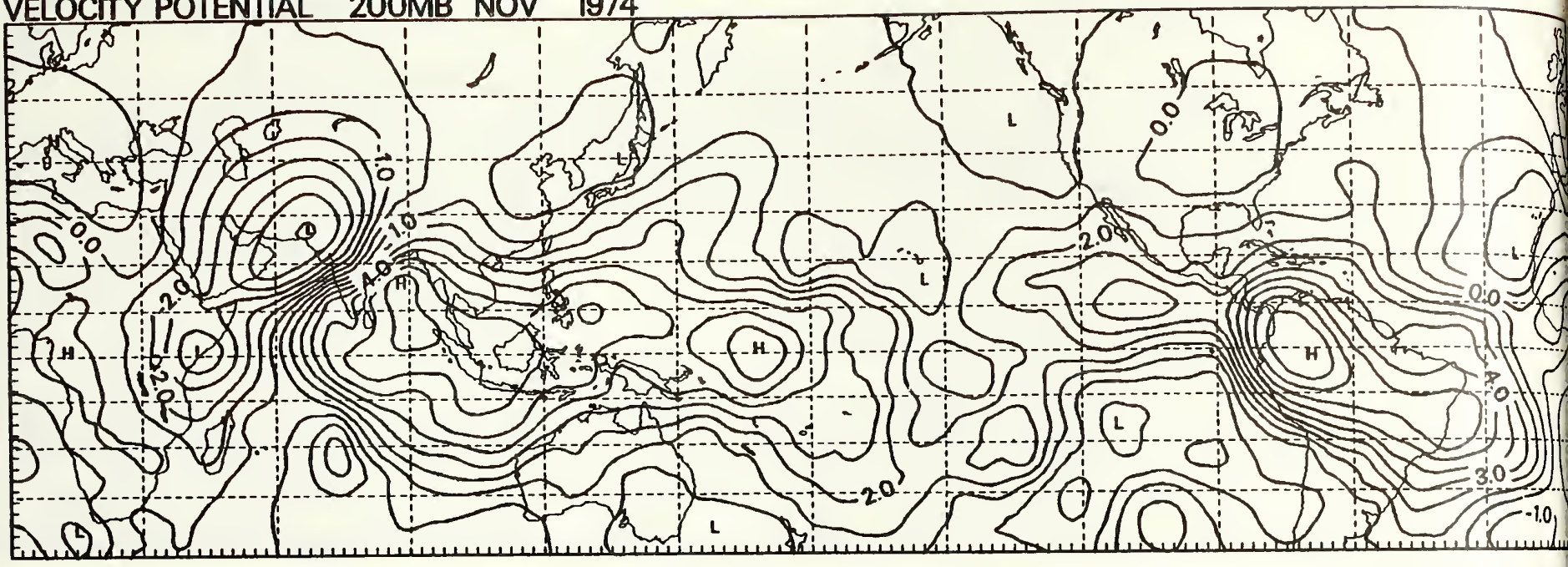
STREAM FUNCTION 200MB NOV 1974



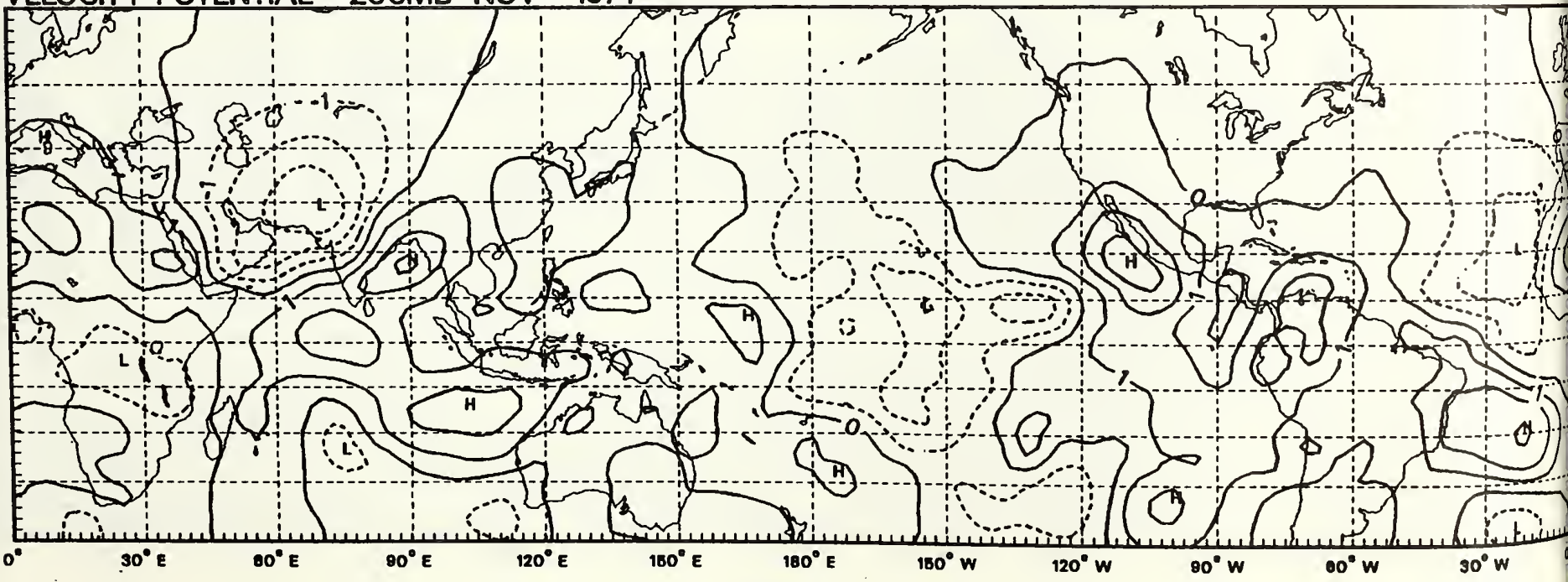
STREAM FUNCTION 200MB NOV 1974



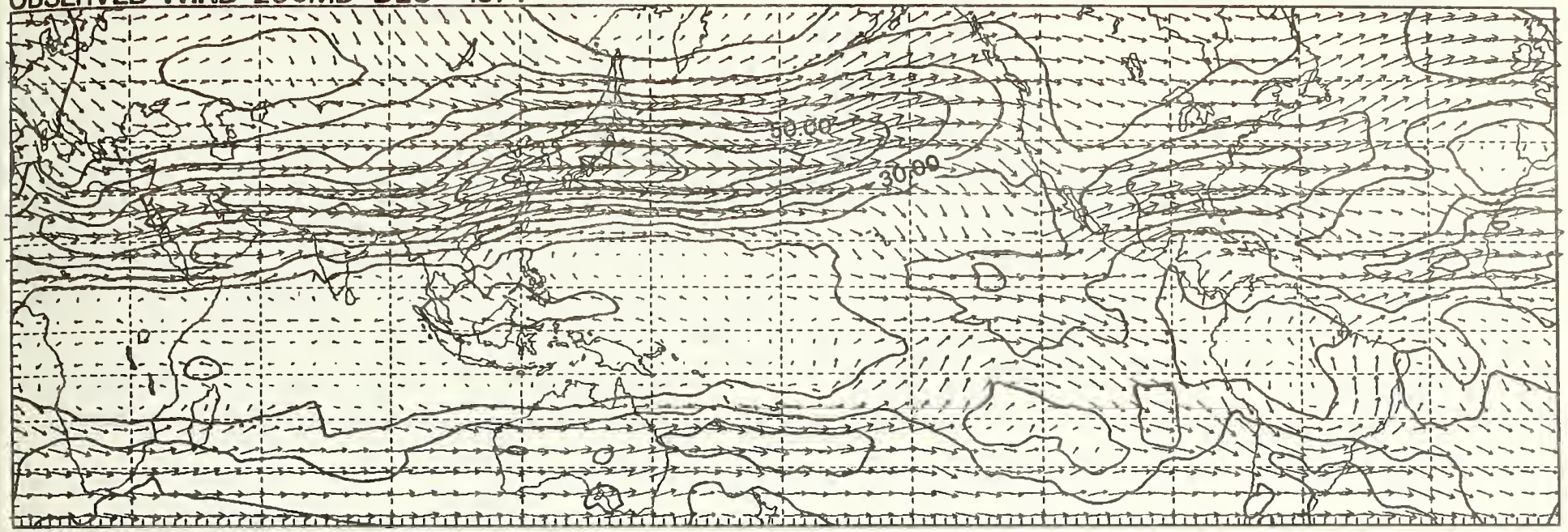
VELOCITY POTENTIAL 200MB NOV 1974



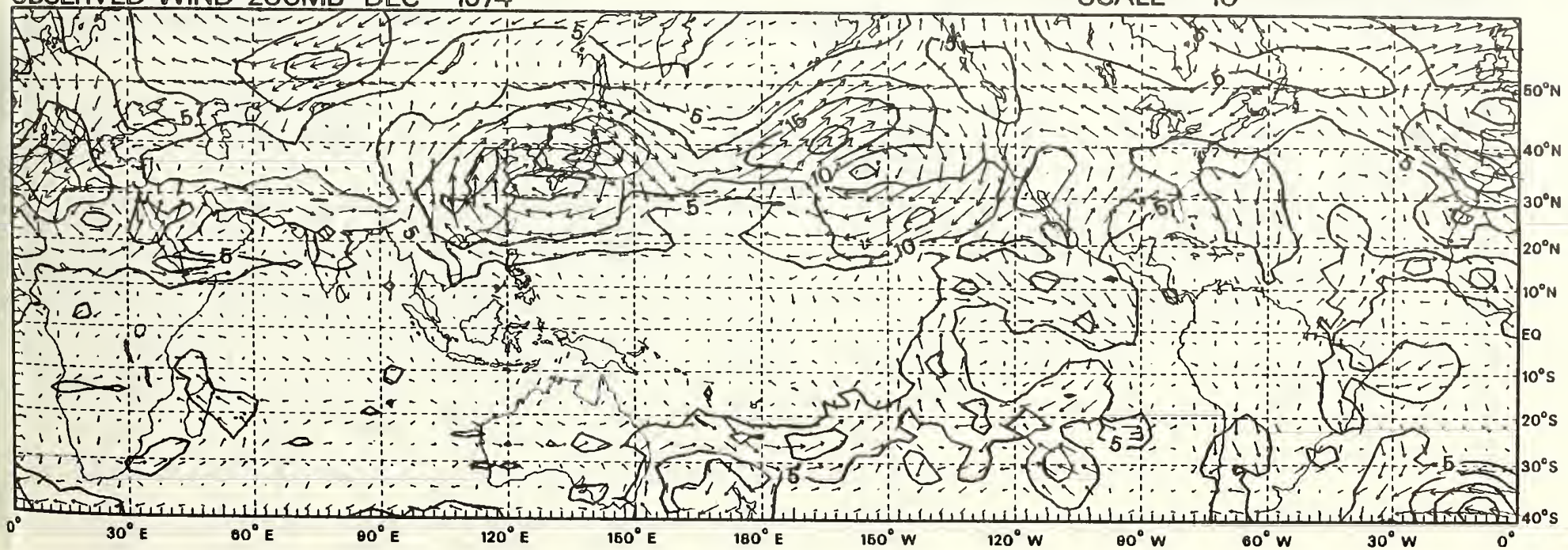
VELOCITY POTENTIAL 200MB NOV 1974



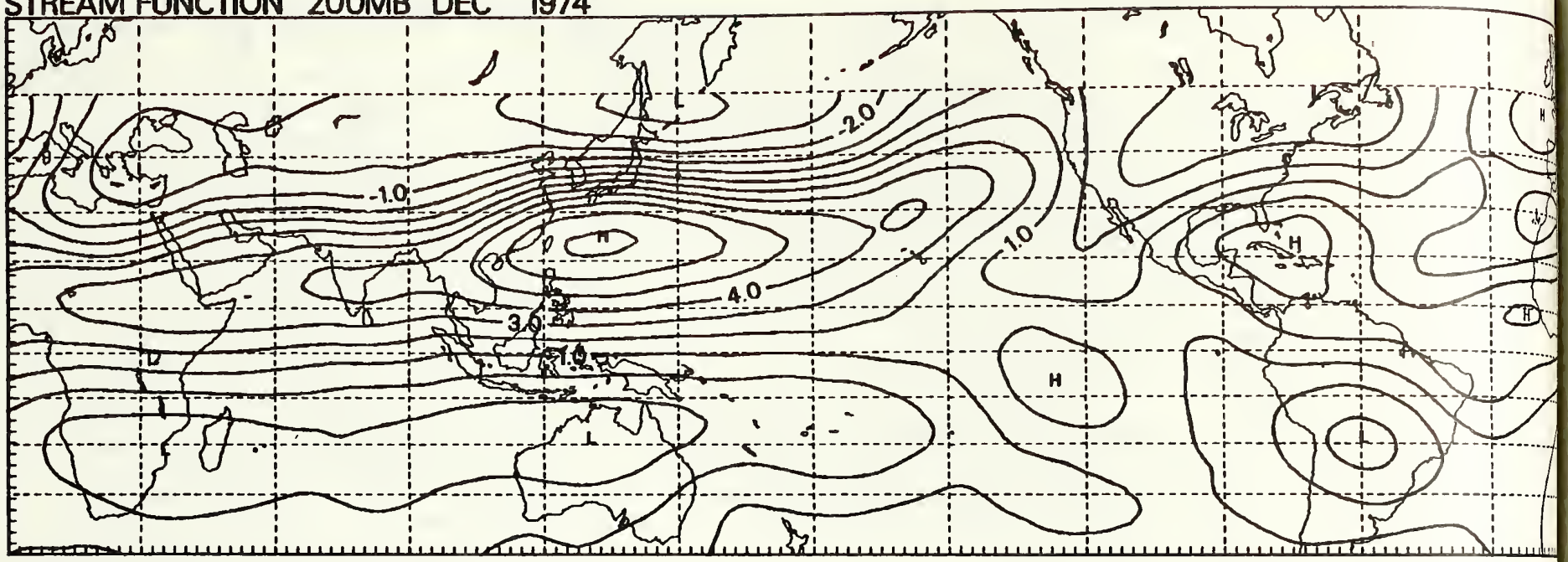
OBSERVED WIND 200MB DEC 1974 SCALE = 20



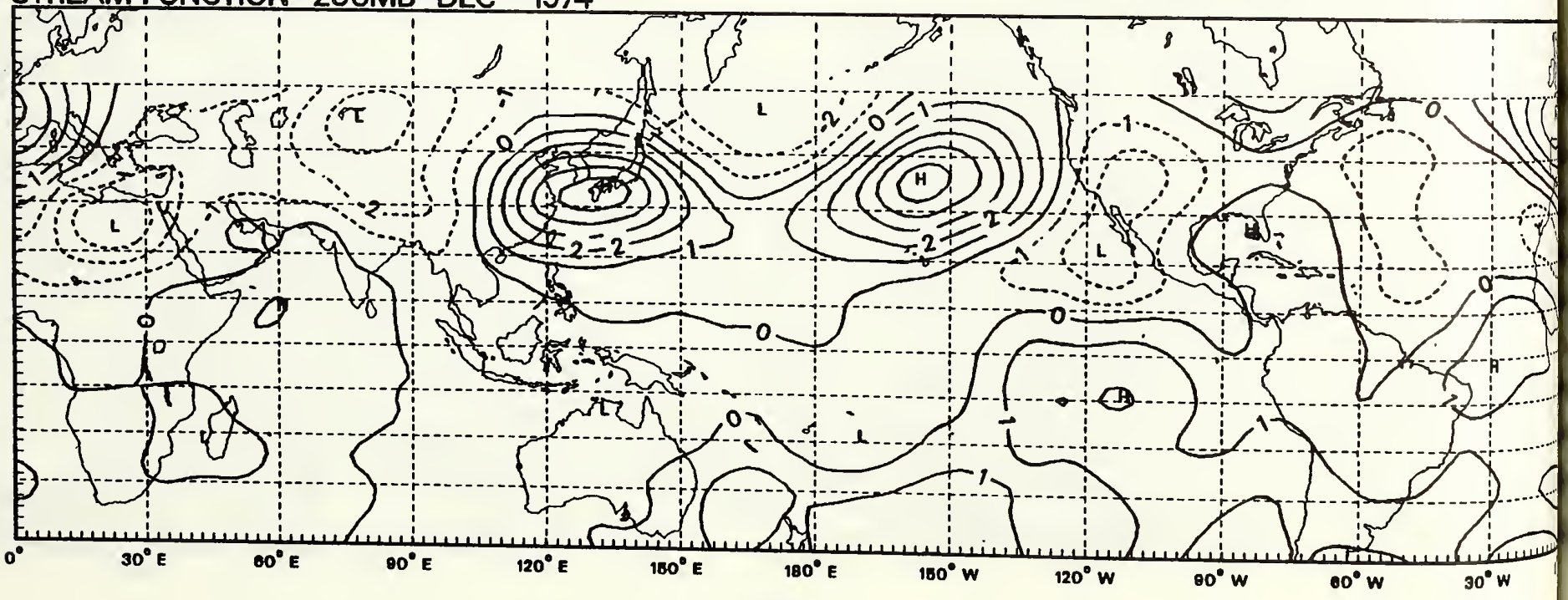
OBSERVED WIND 200MB DEC 1974 SCALE = 10



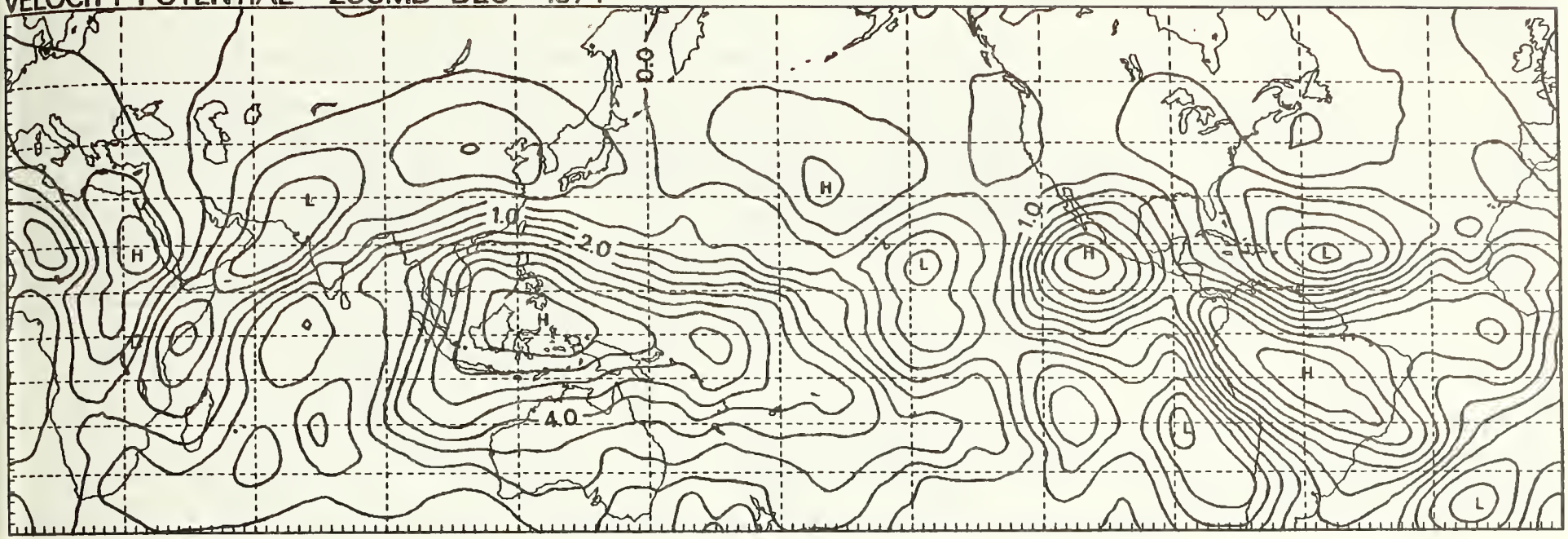
STREAM FUNCTION 200MB DEC 1974



STREAM FUNCTION 200MB DEC 1974



VELOCITY POTENTIAL 200MB DEC 1974



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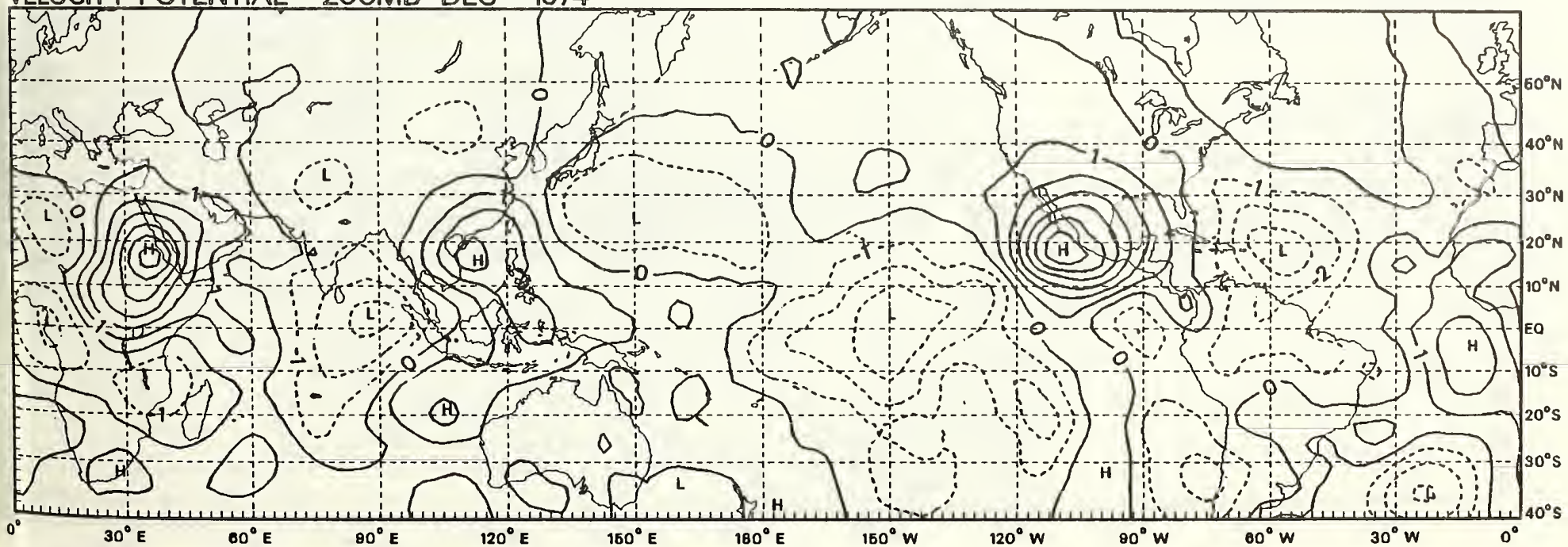
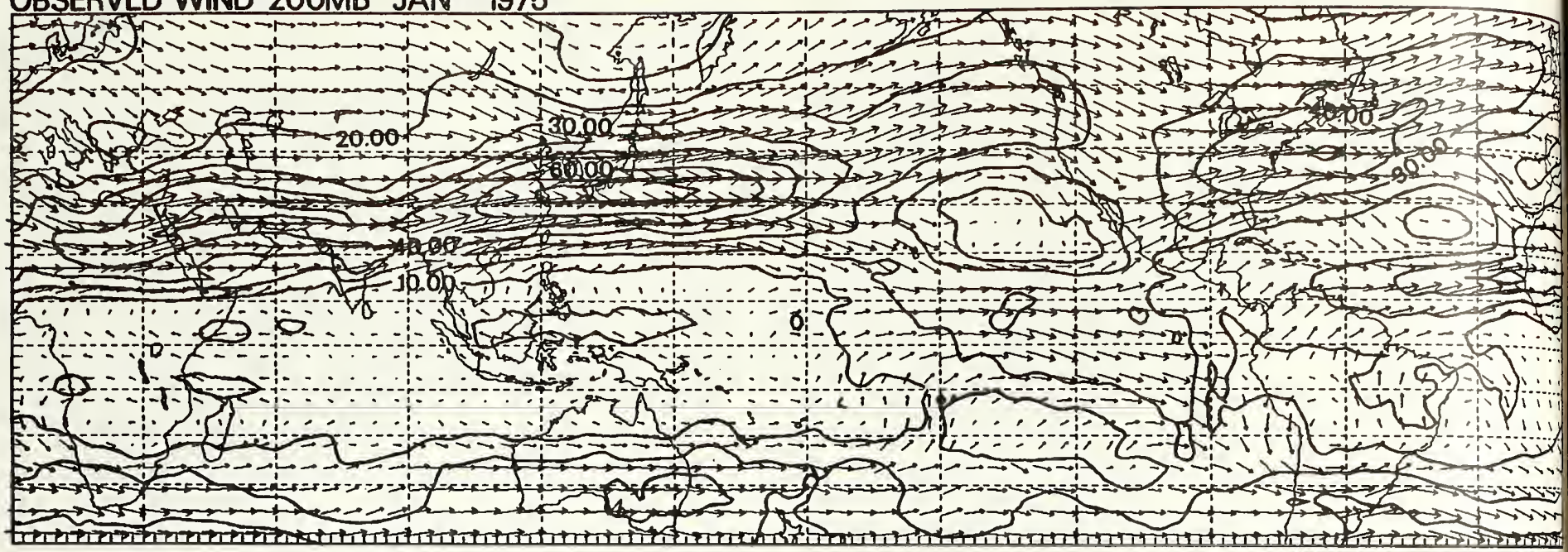


OBSERVED WIND 200MB JAN 1975 SCALE = 20



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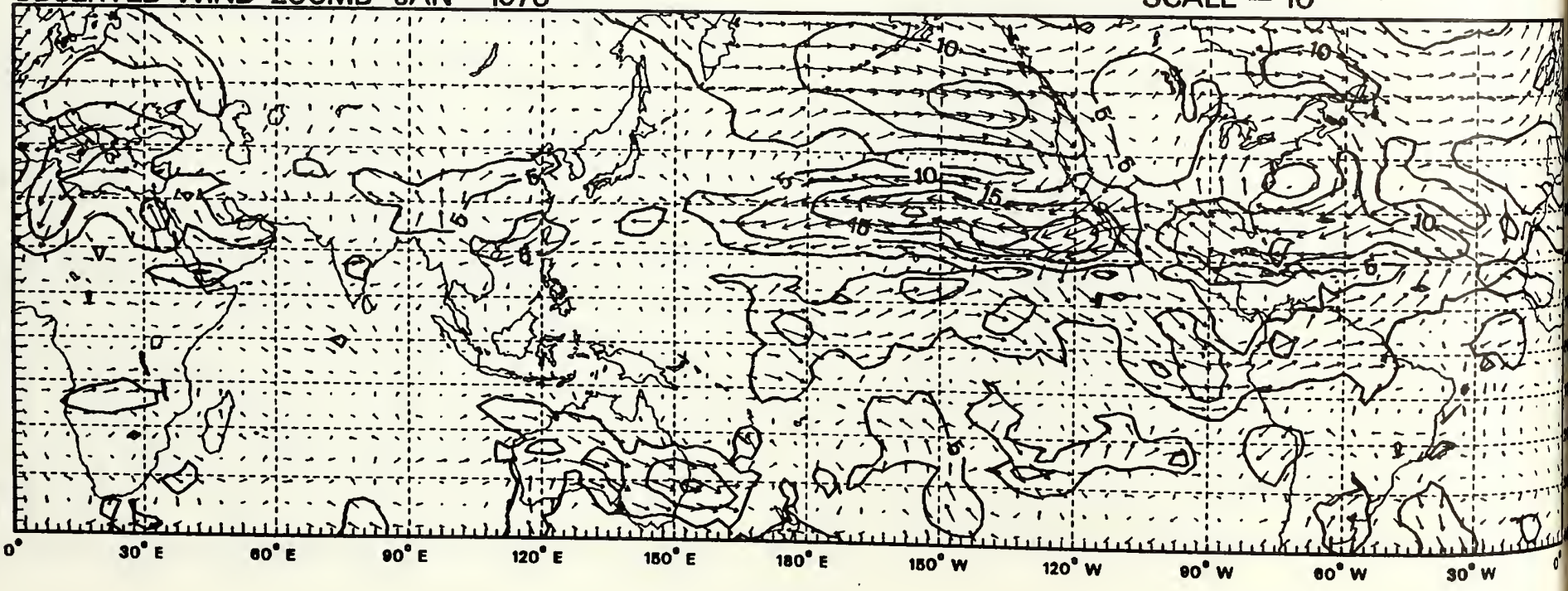
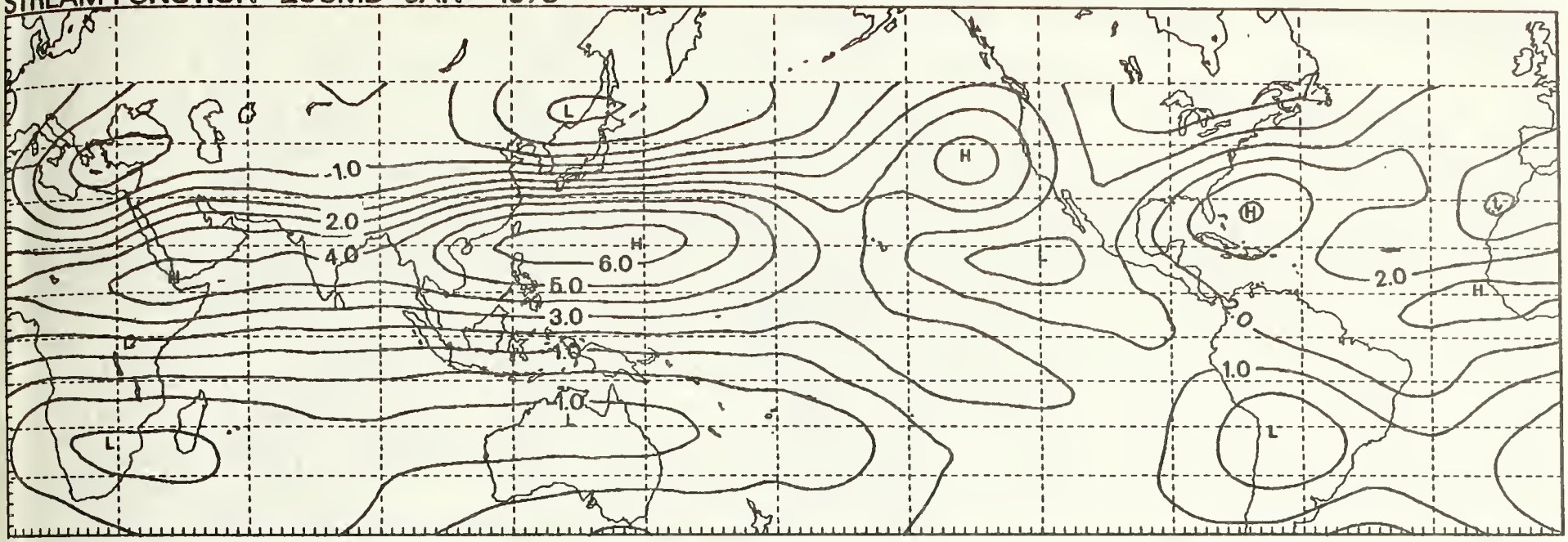
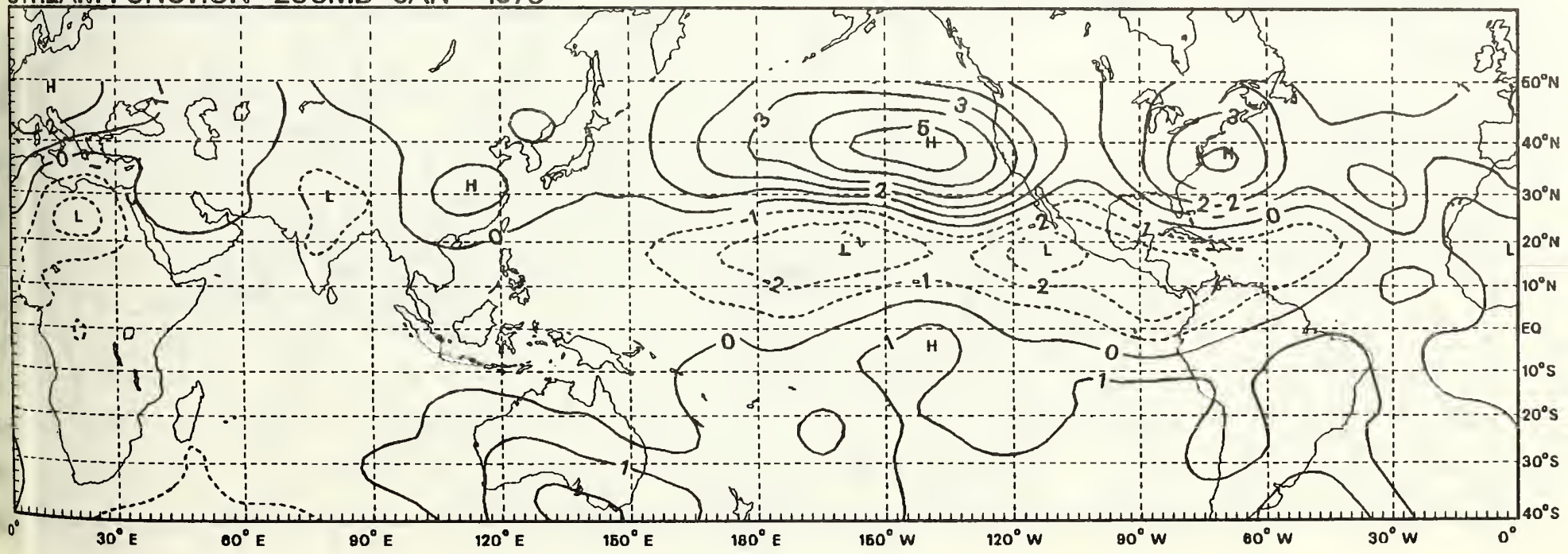


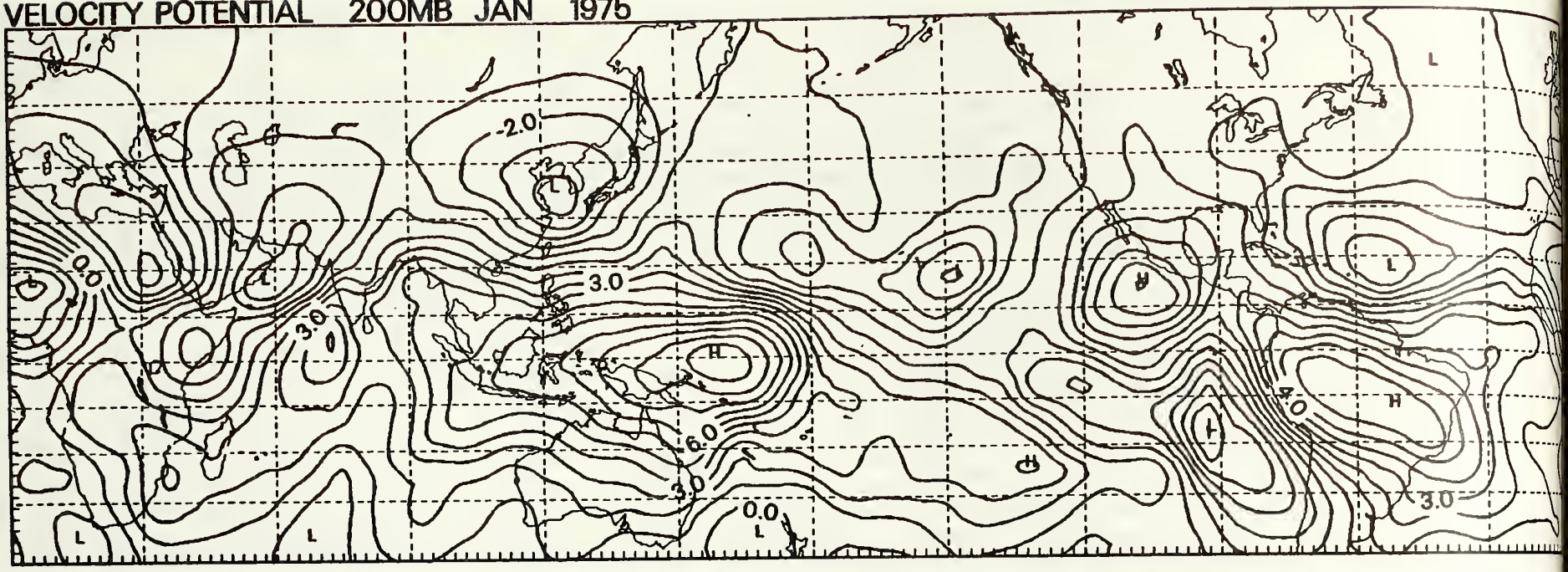
STREAM FUNCTION 200MB JAN 1975



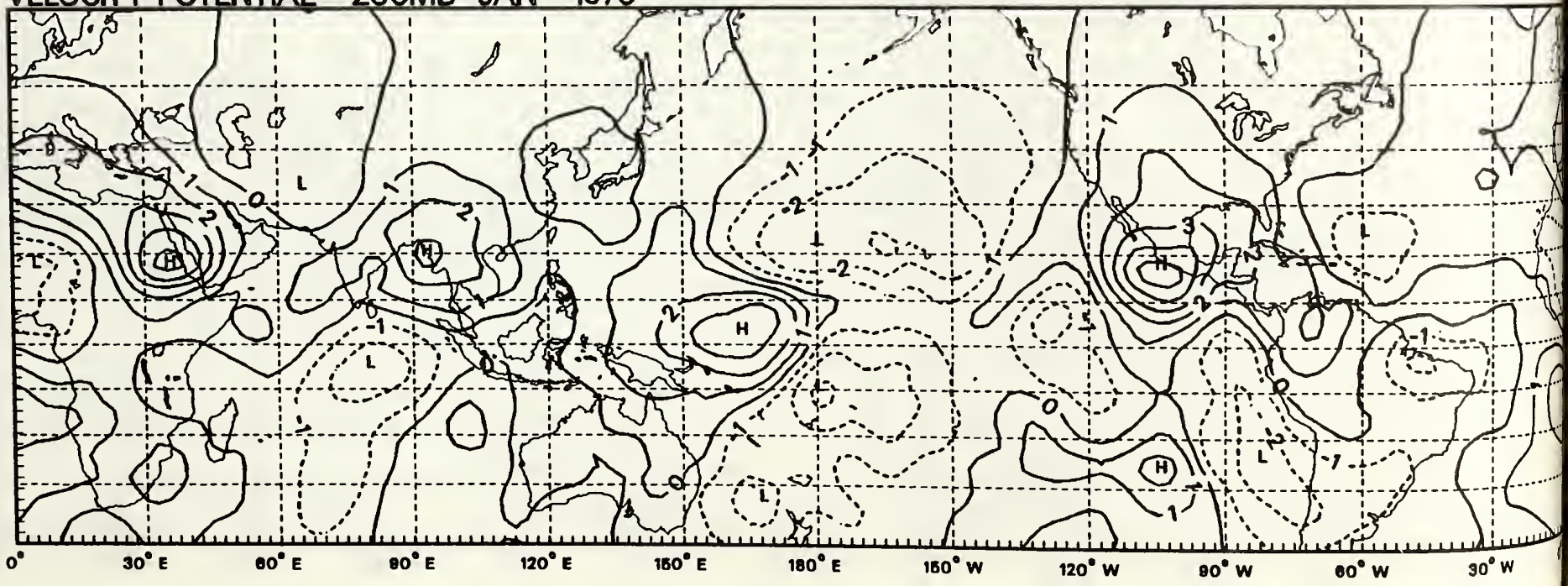
STREAM FUNCTION 200MB JAN 1975



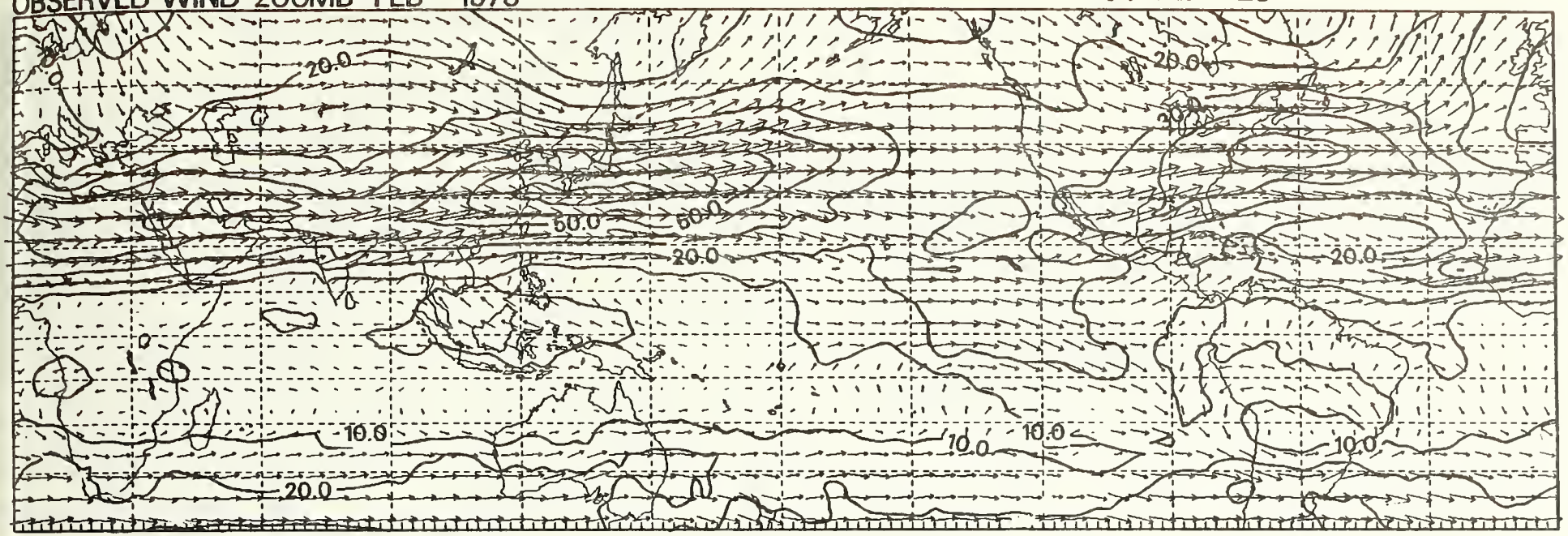
VELOCITY POTENTIAL 200MB JAN 1975



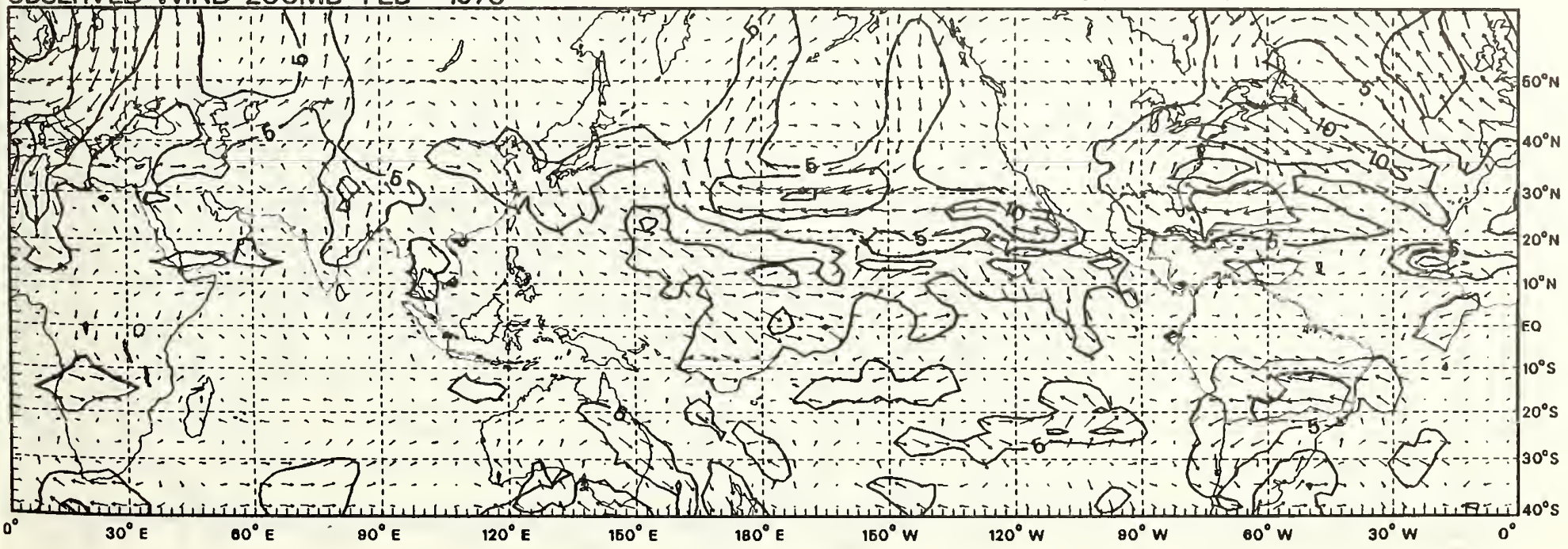
VELOCITY POTENTIAL 200MB JAN 1975



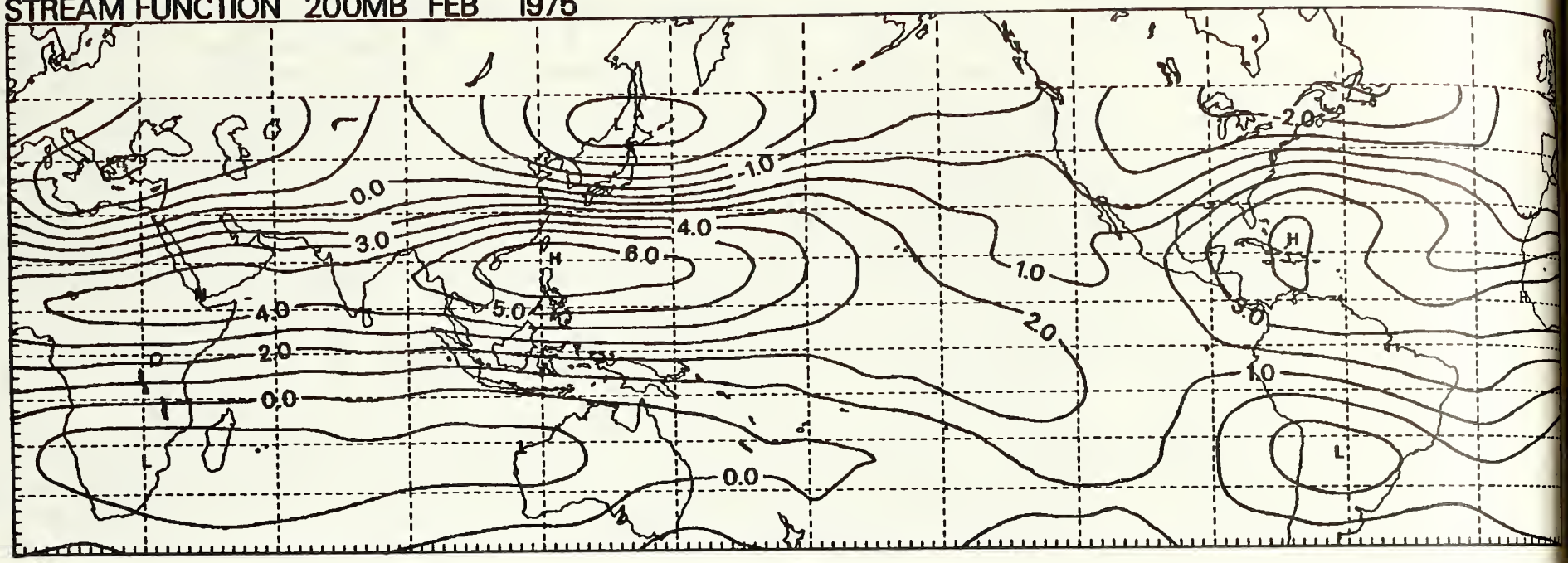
OBSERVED WIND 200MB FEB 1975 SCALE = 20



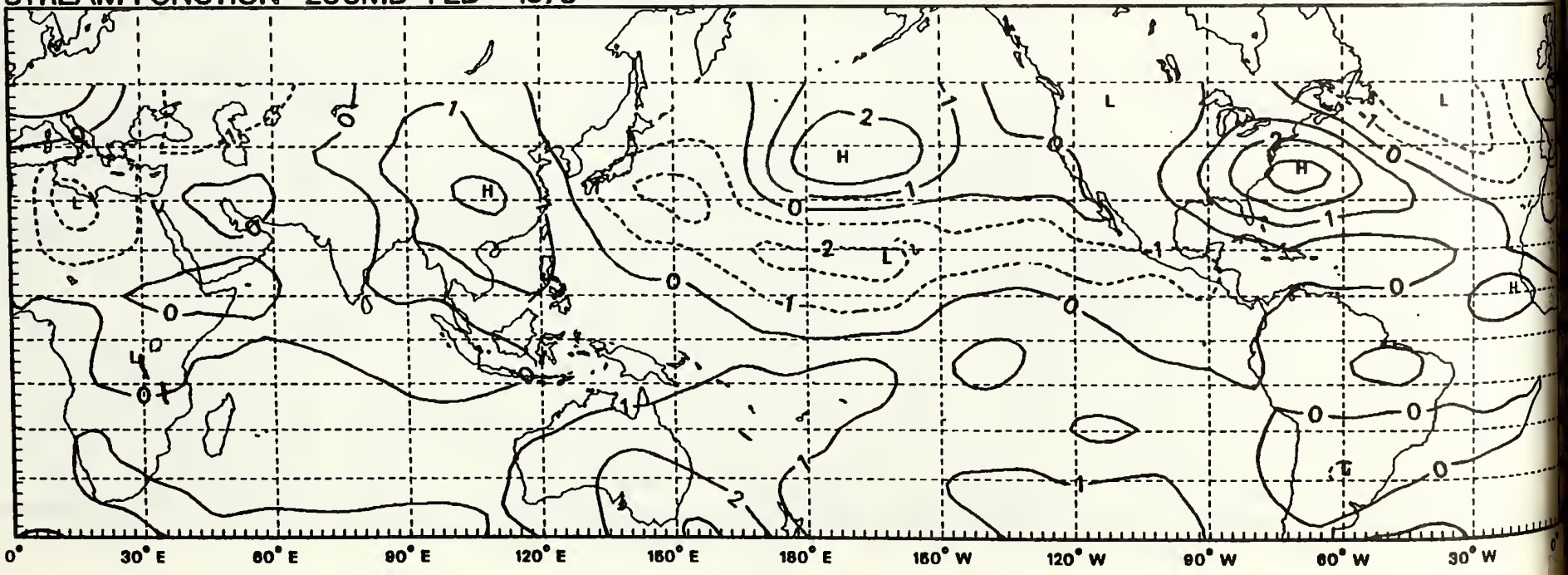
OBSERVED WIND 200MB FEB 1975 SCALE = 10



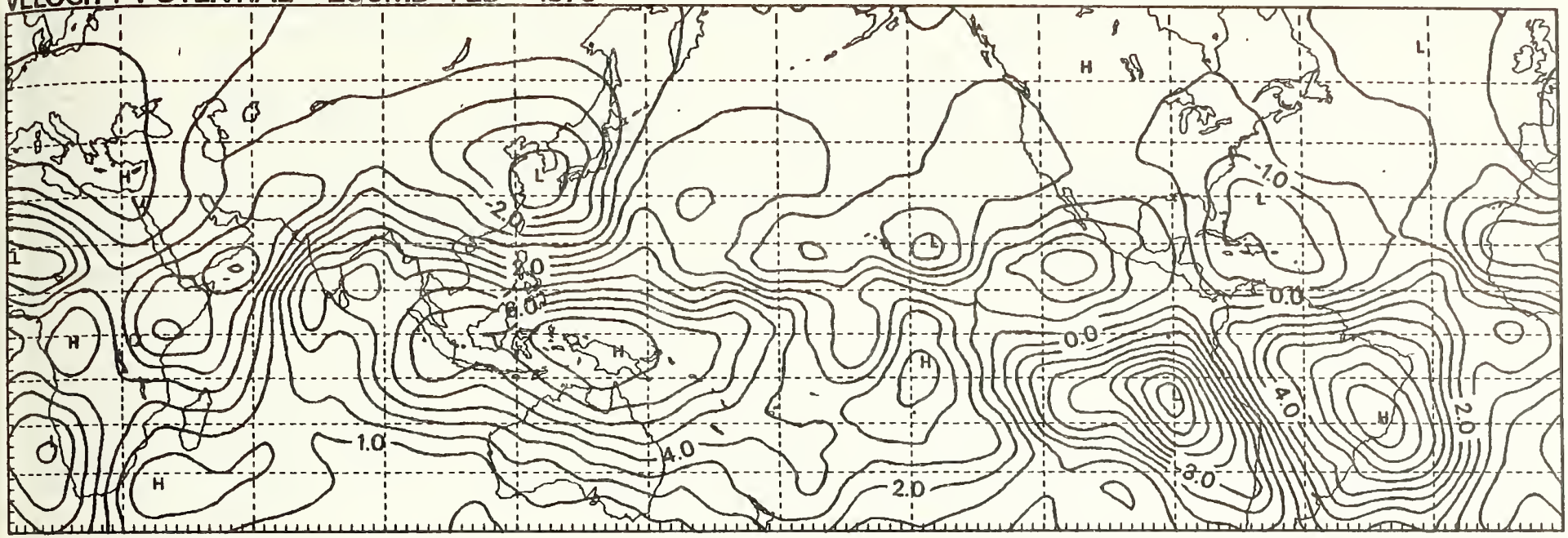
STREAM FUNCTION 200MB FEB 1975



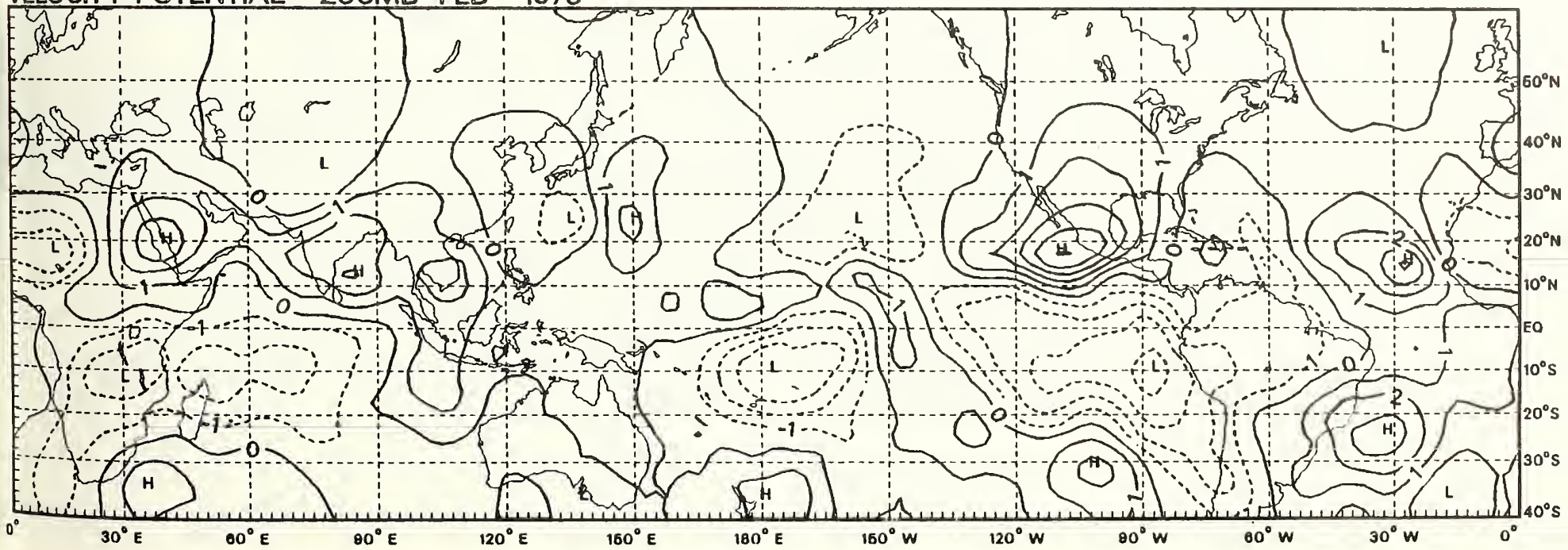
STREAM FUNCTION 200MB FEB 1975



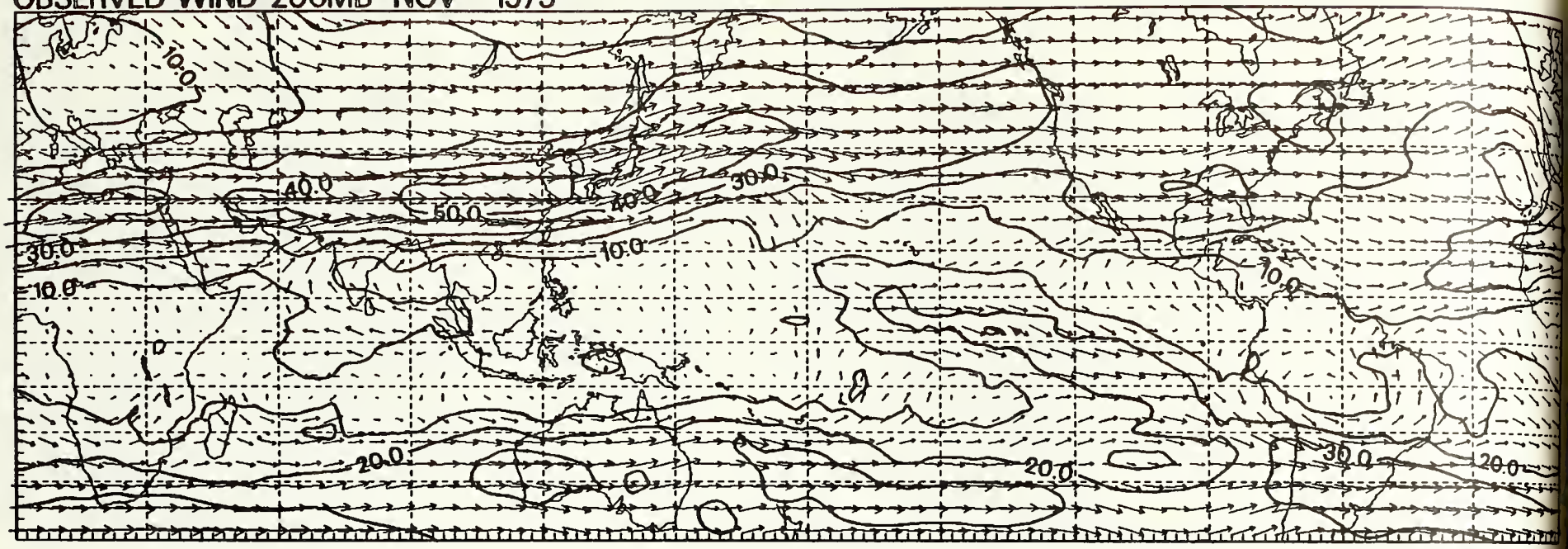
VELOCITY POTENTIAL 200MB FEB 1975



VELOCITY POTENTIAL 200MB FEB 1975



OBSERVED WIND 200MB NOV 1975 SCALE = 20



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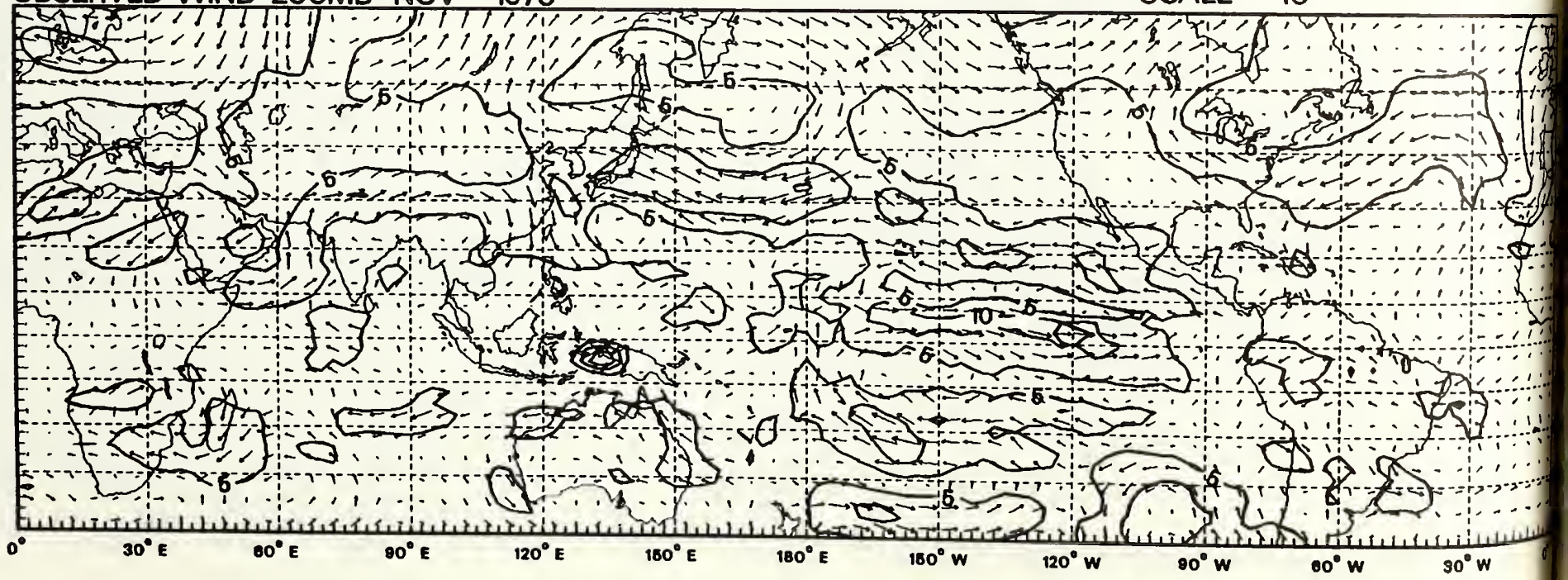

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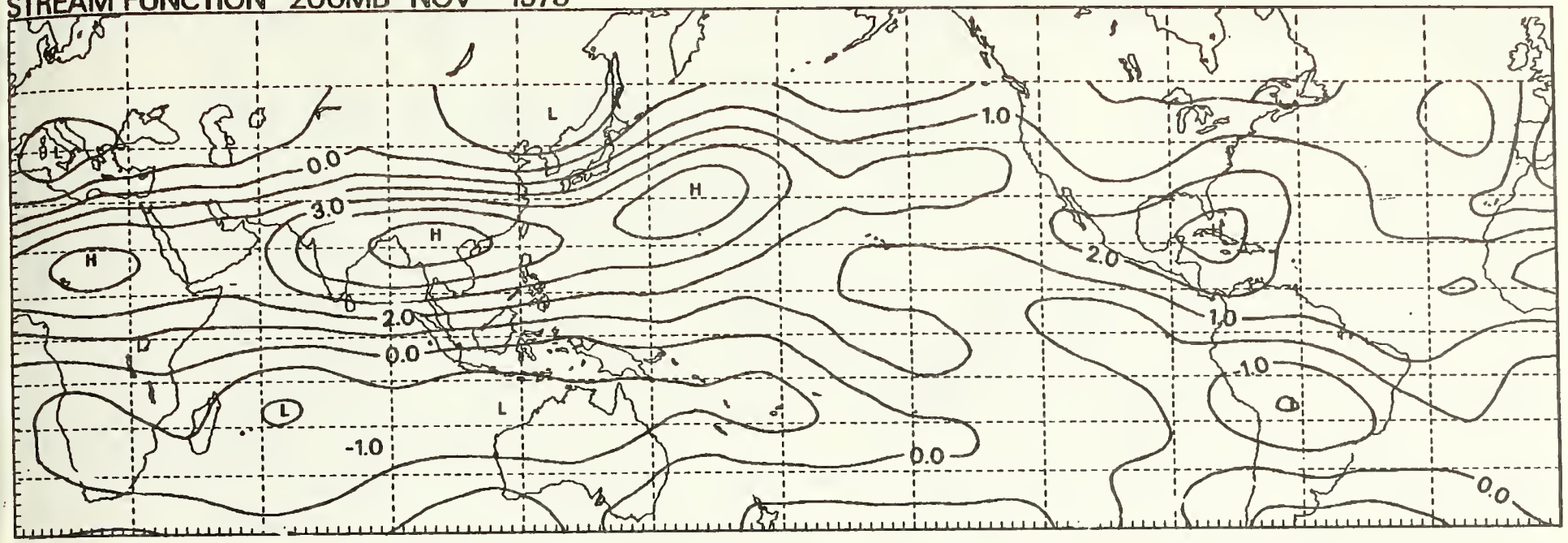
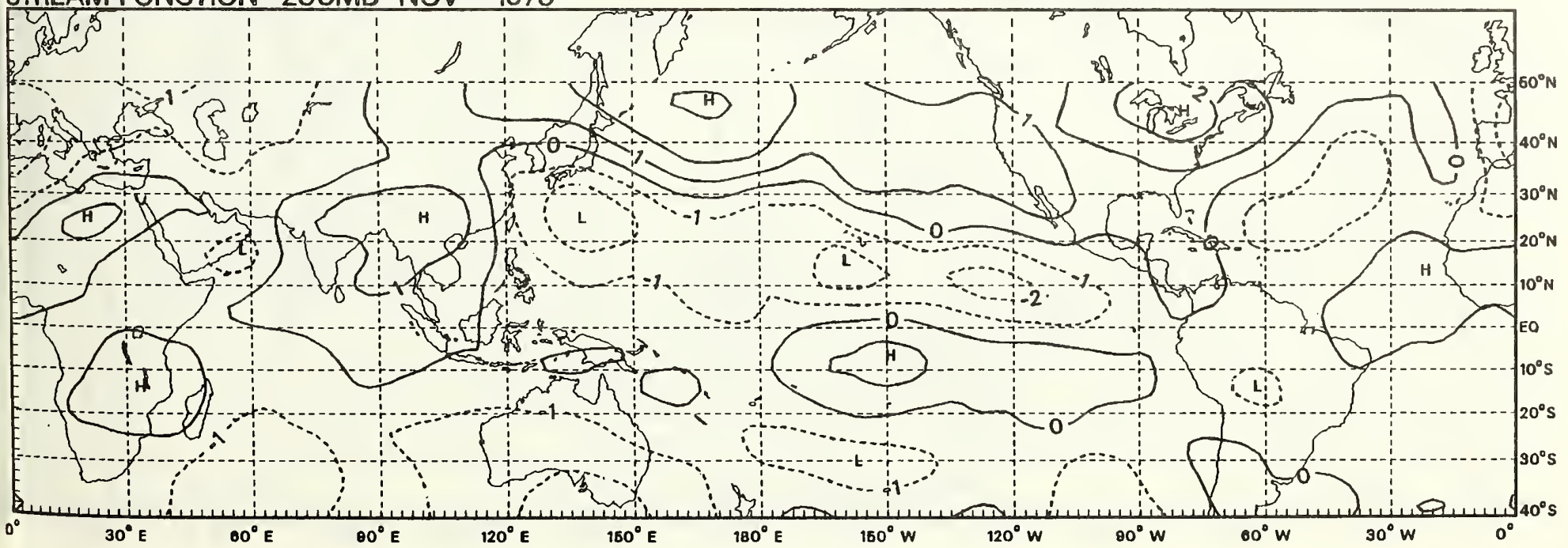
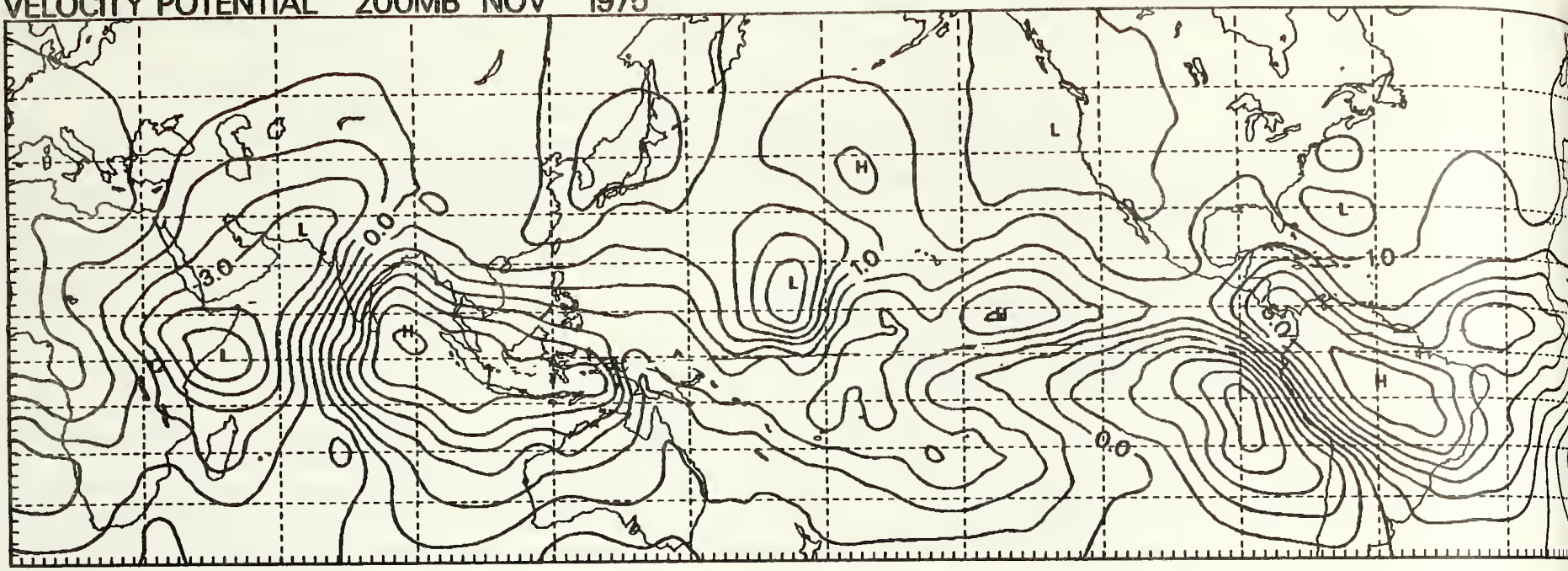


STREAM FUNCTION 200MB NOV 1975



VELOCITY POTENTIAL 200MB NOV 1975



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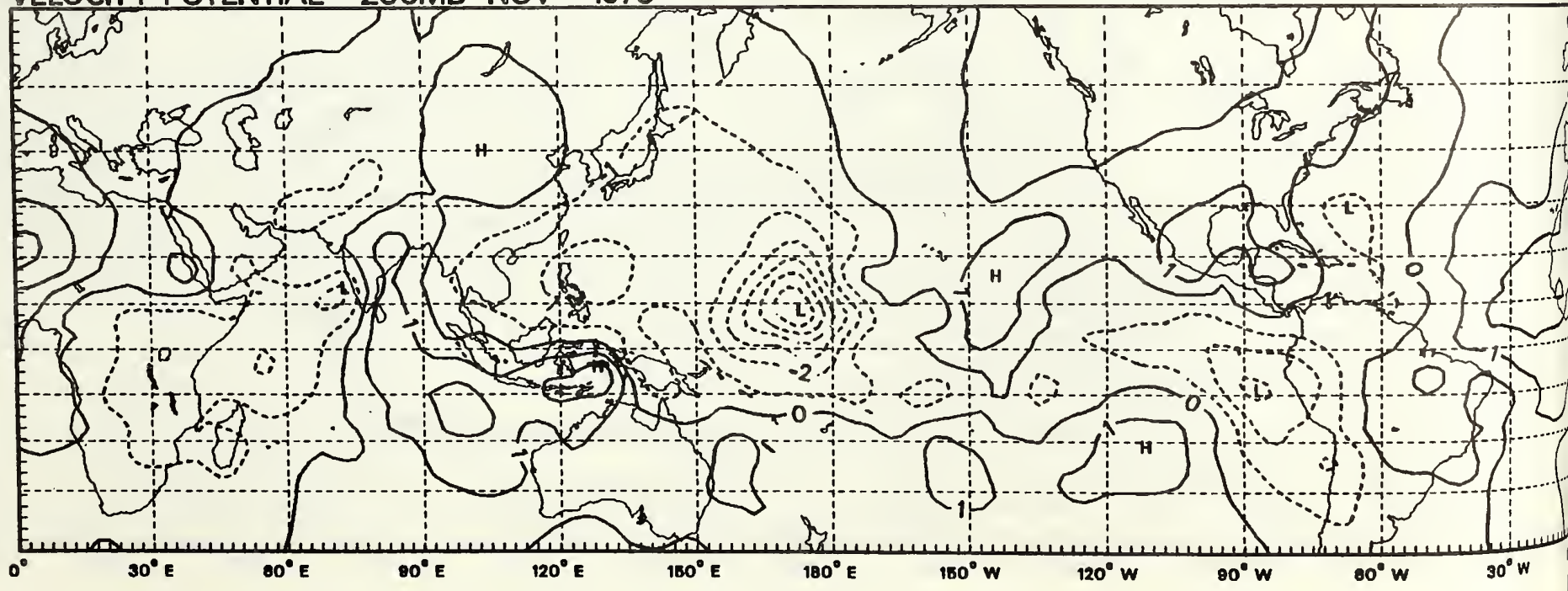

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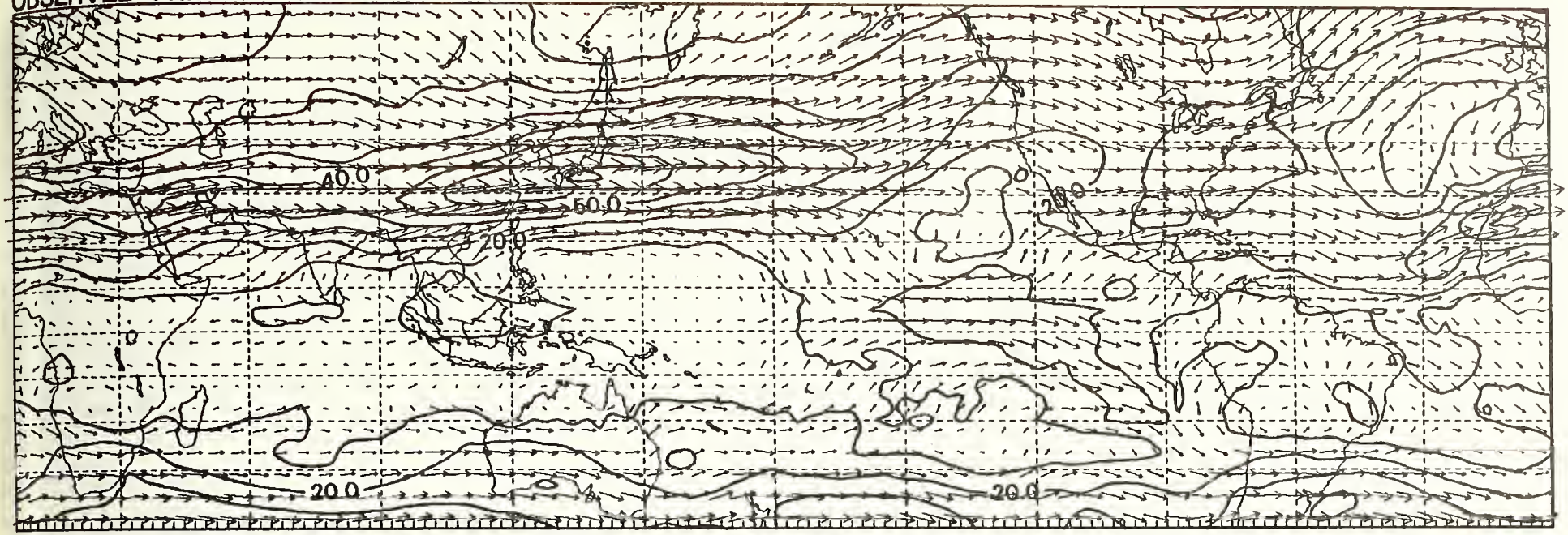

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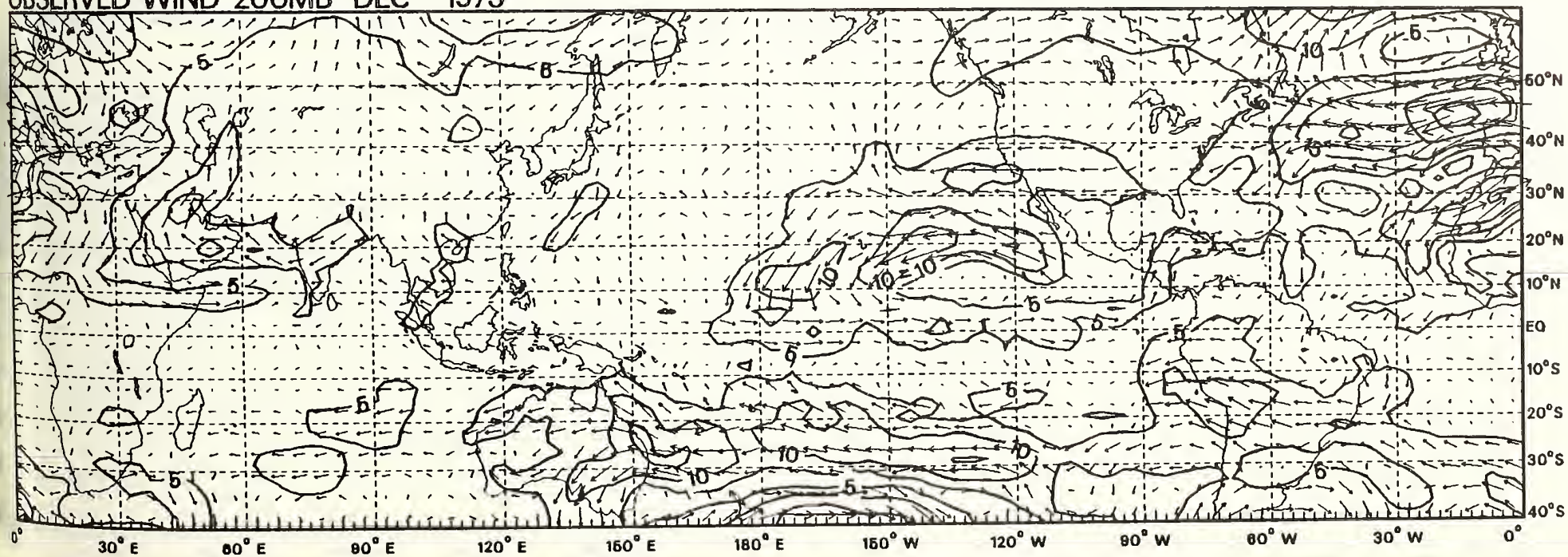

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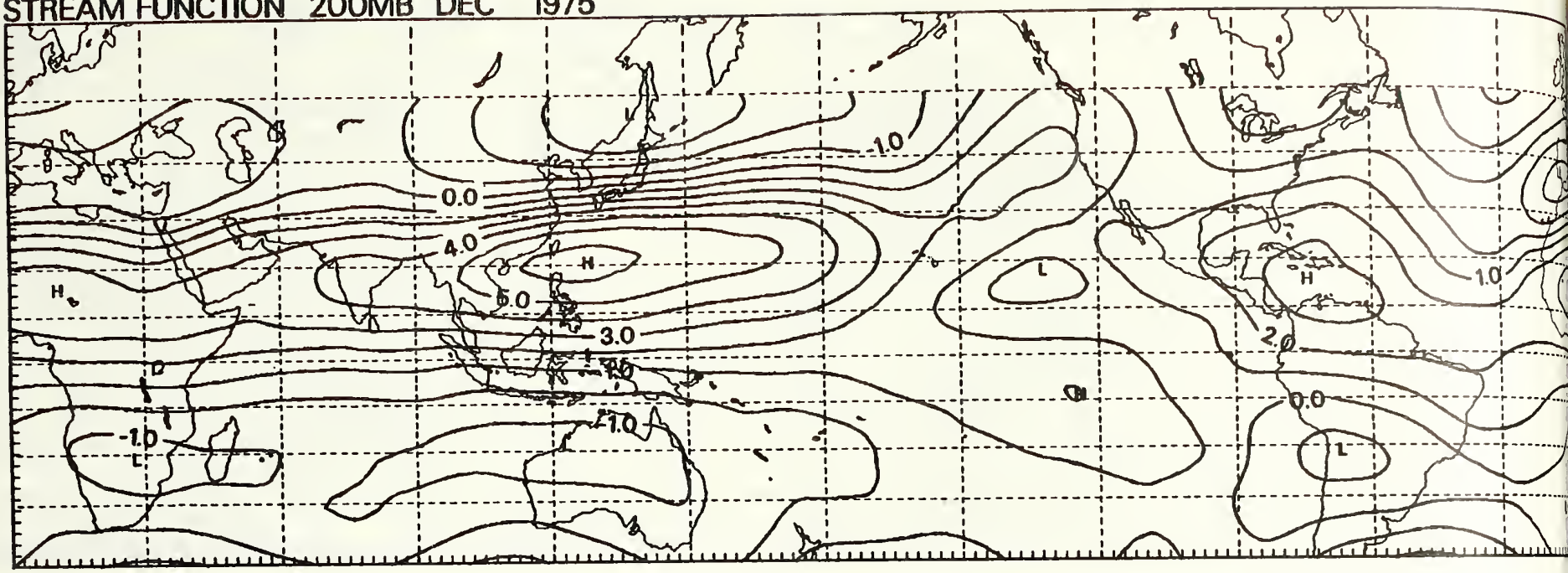
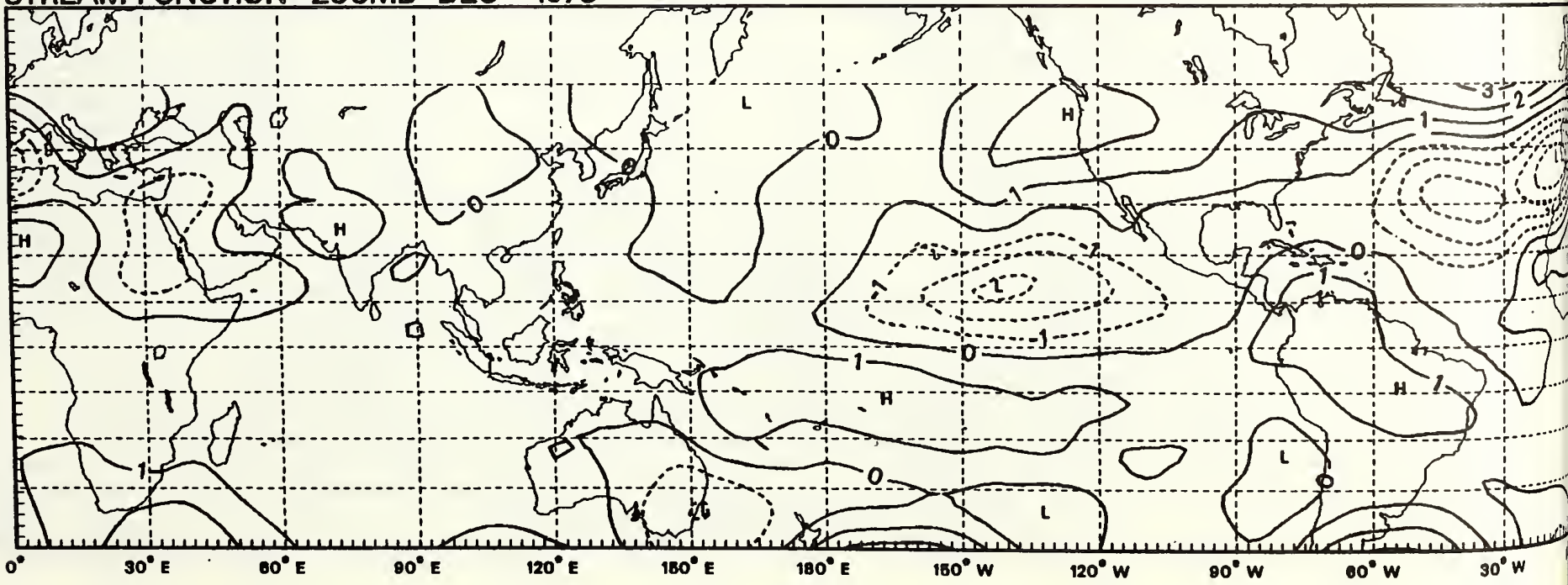


STREAM FUNCTION 200MB DEC 1975



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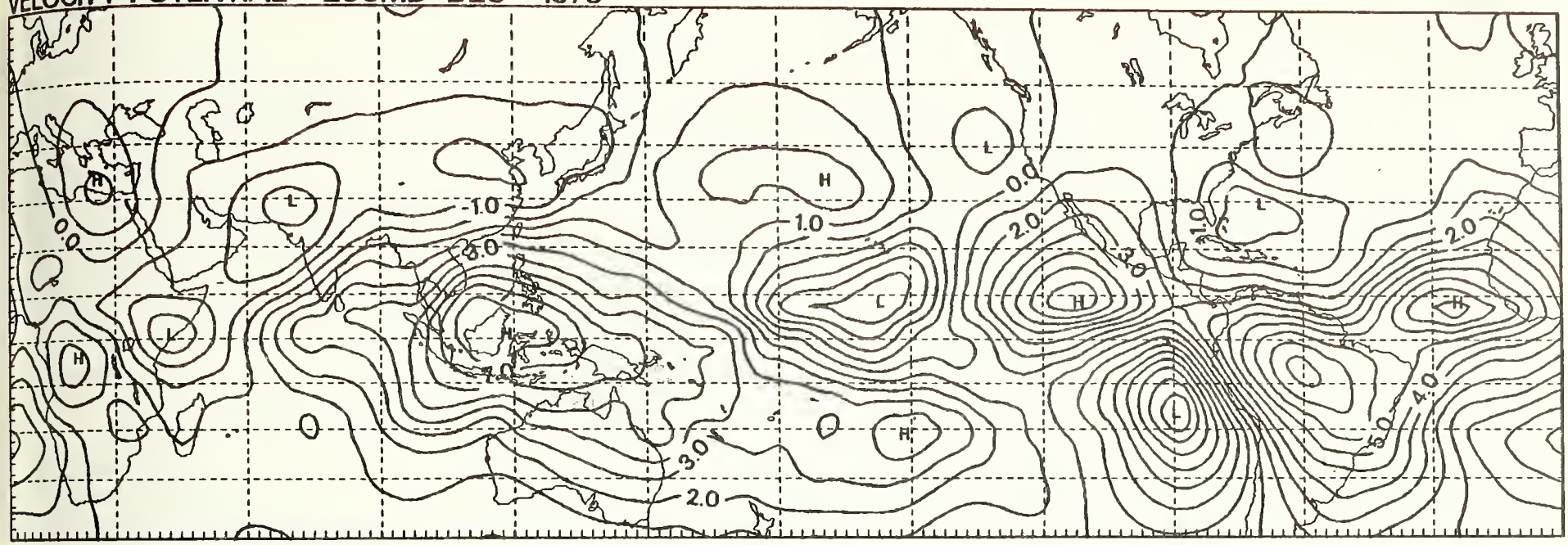

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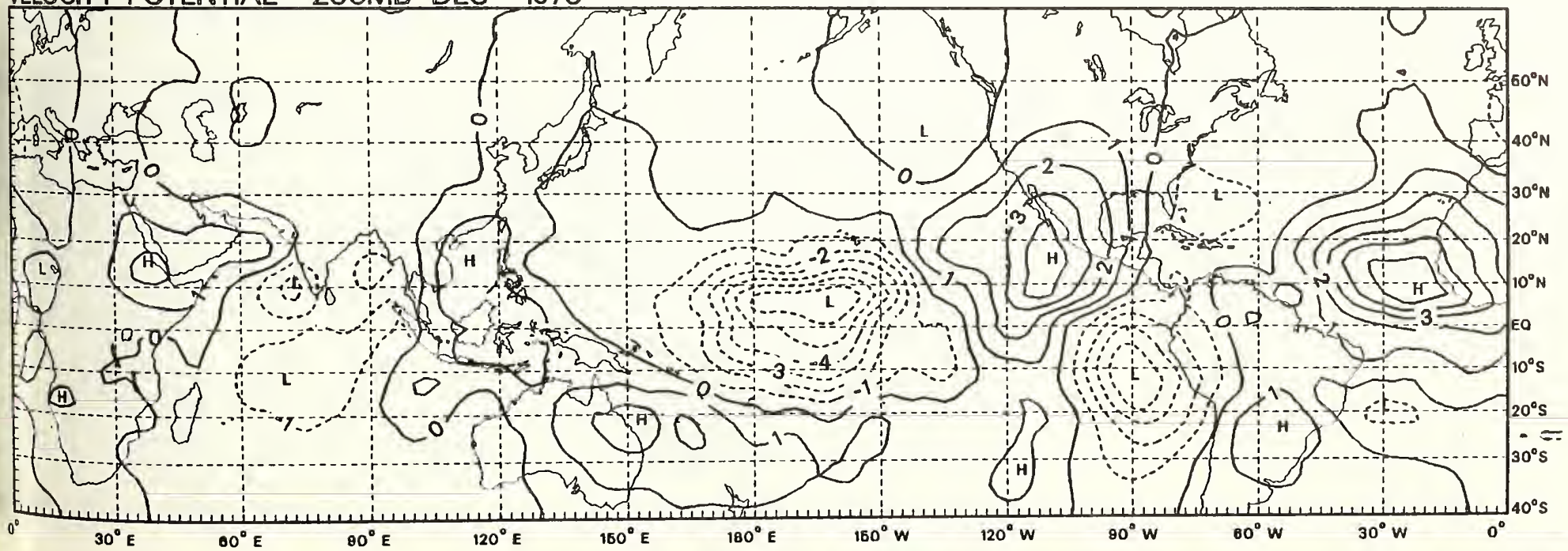

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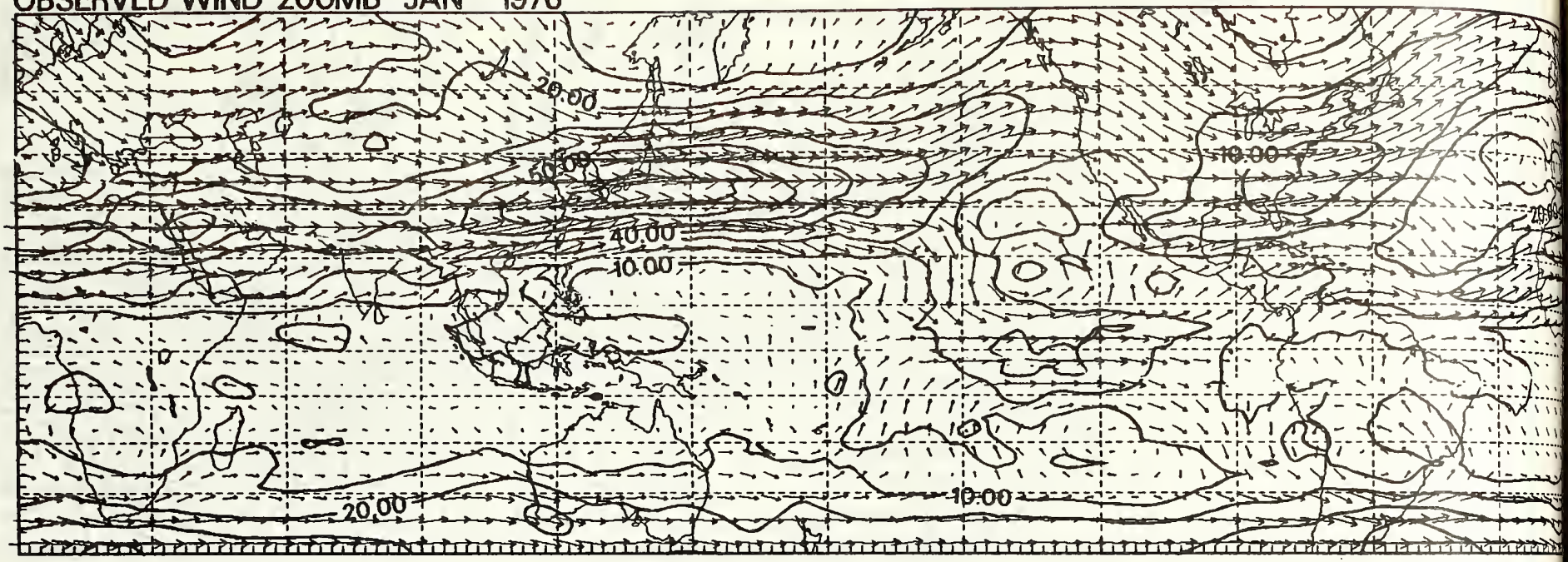

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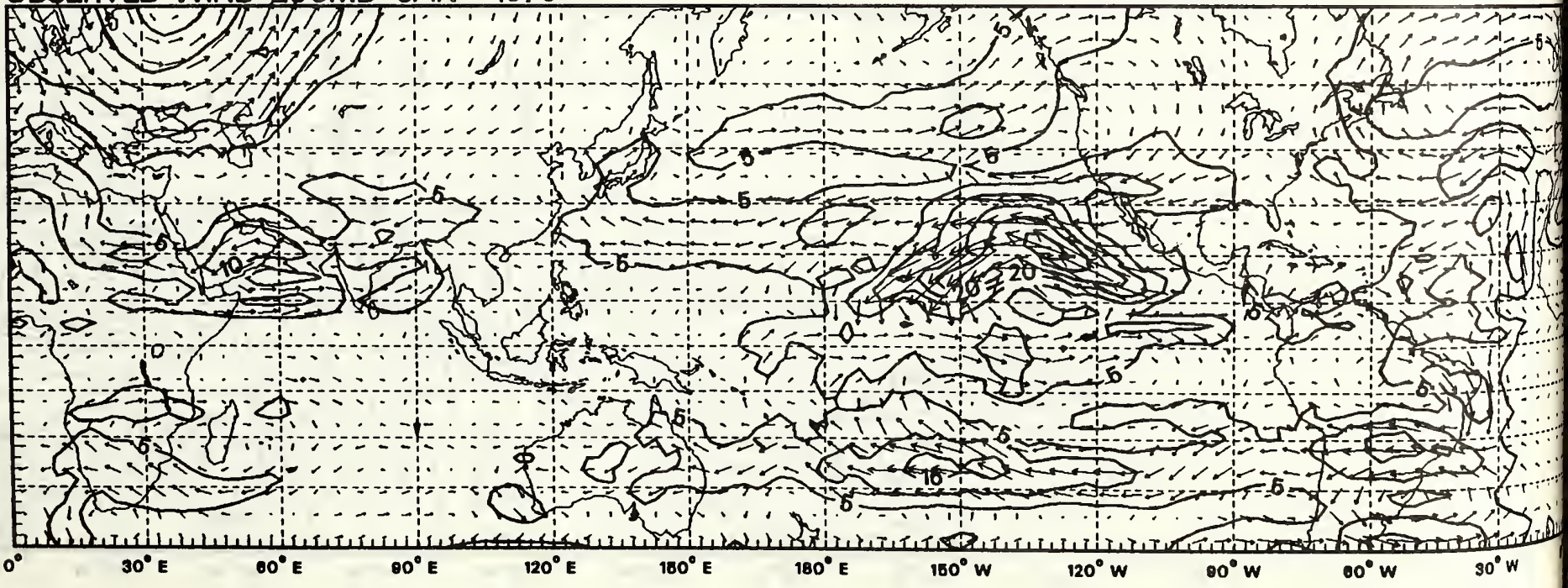
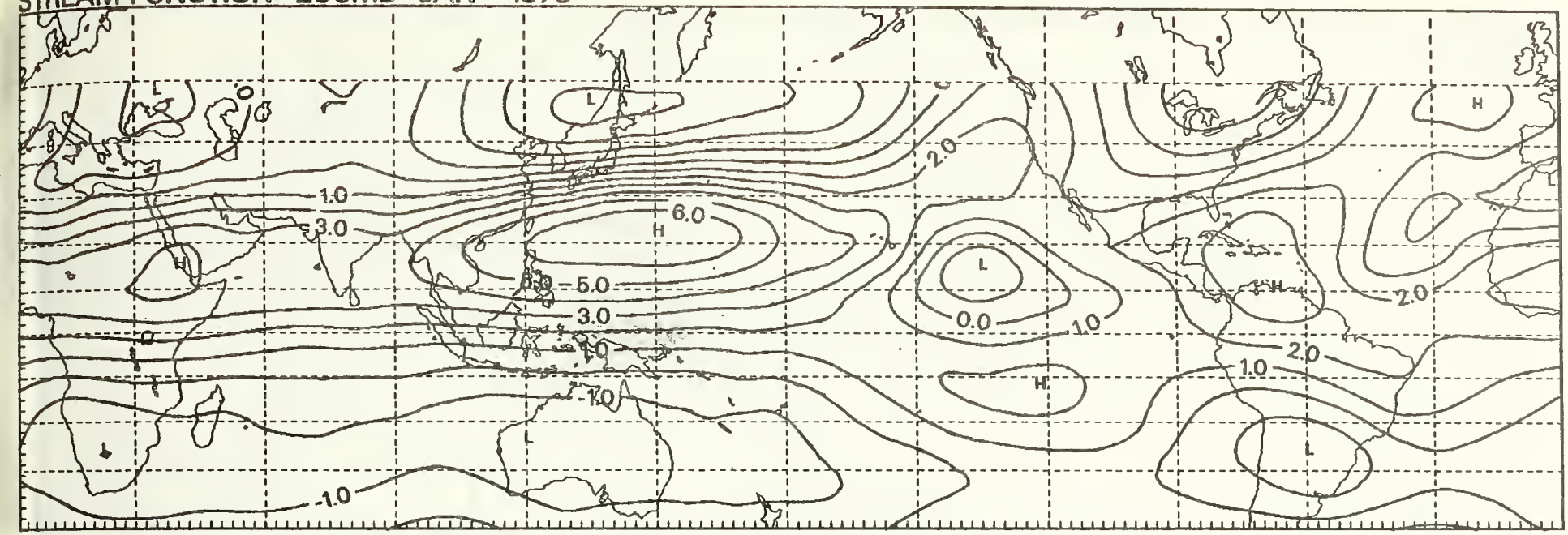


STREAM FUNCTION 200MB JAN 1976



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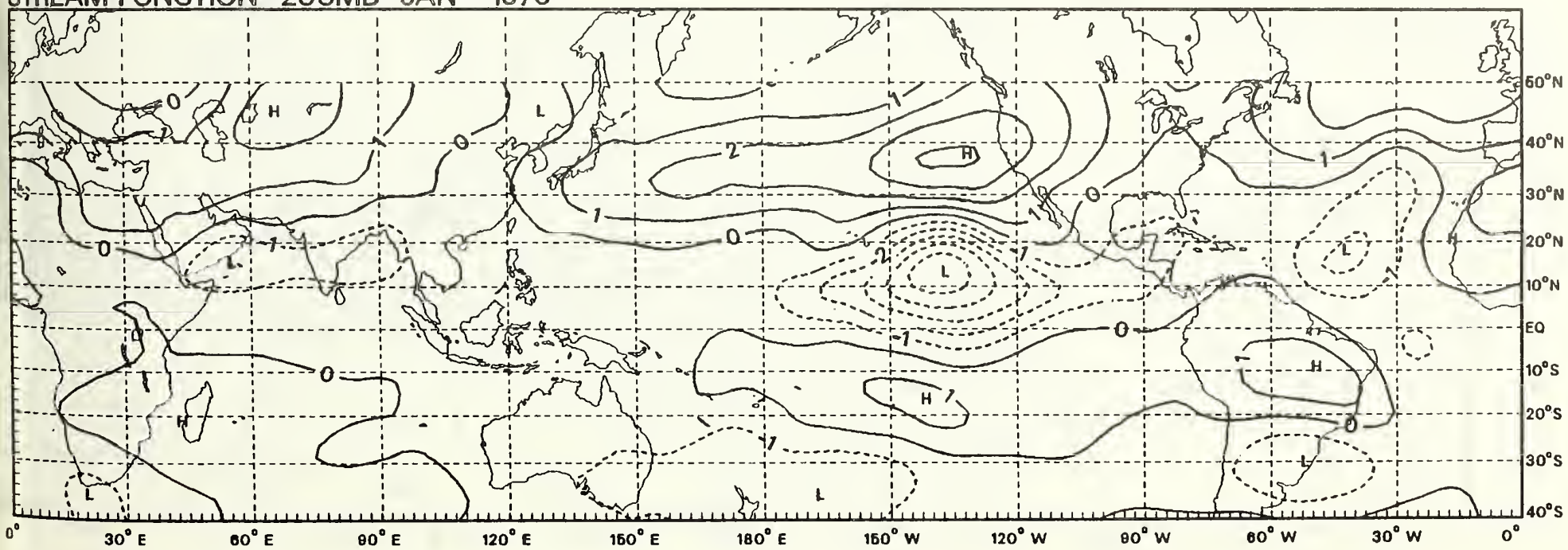
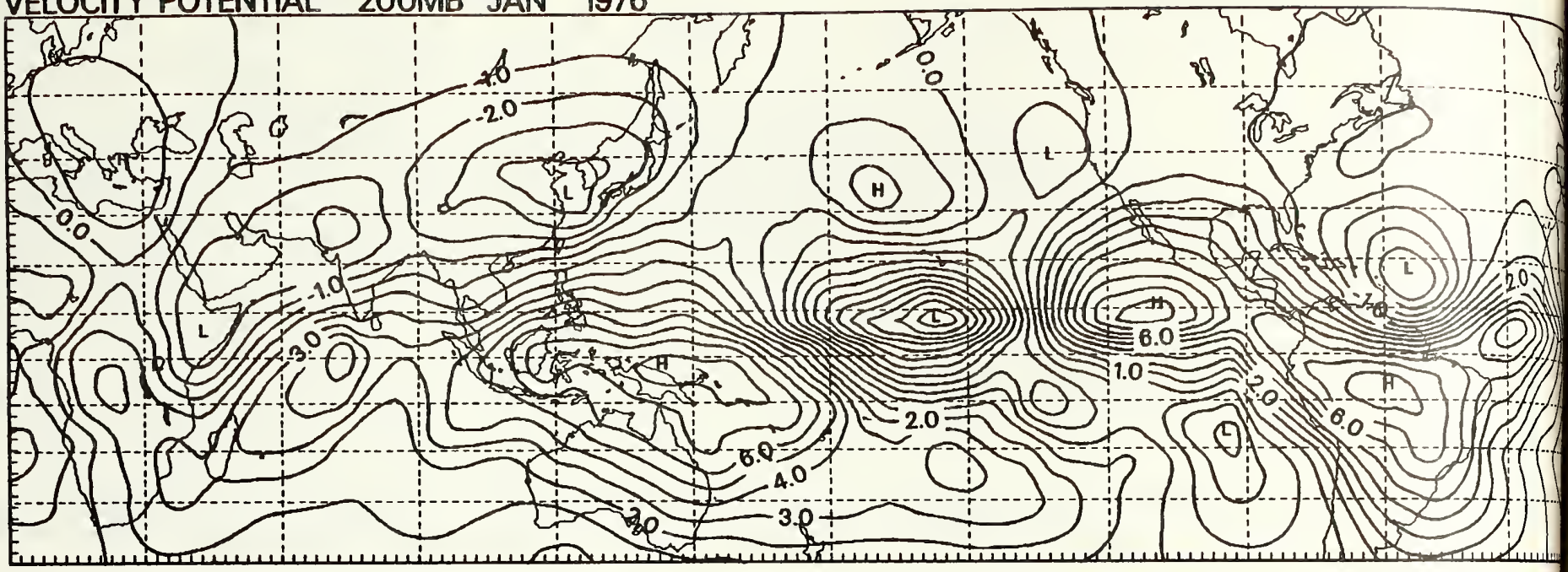


VELOCITY POTENTIAL 200MB JAN 1976



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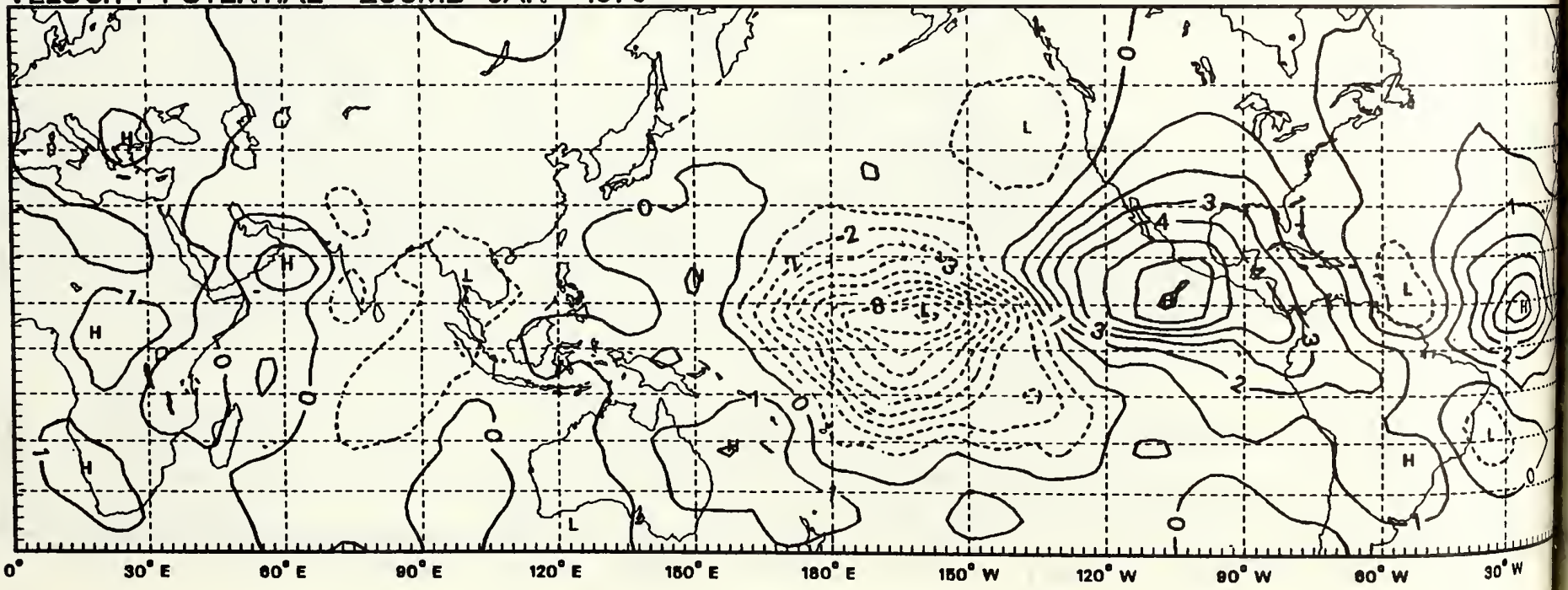

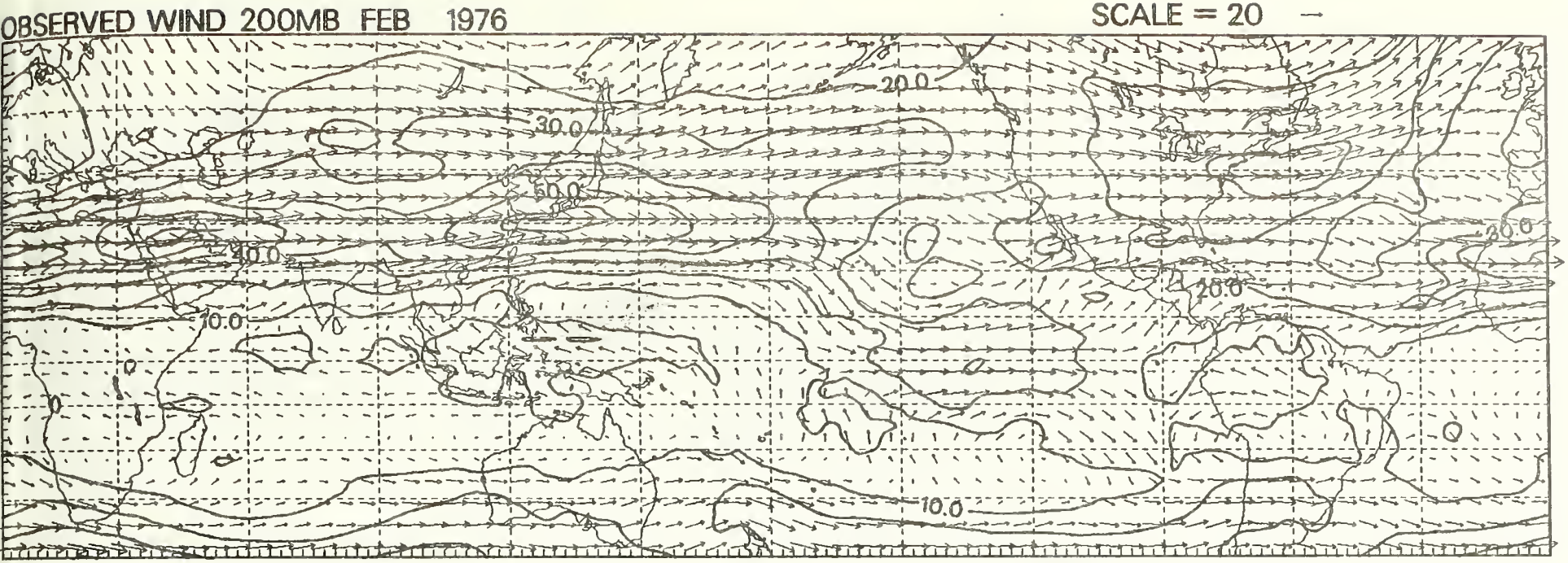
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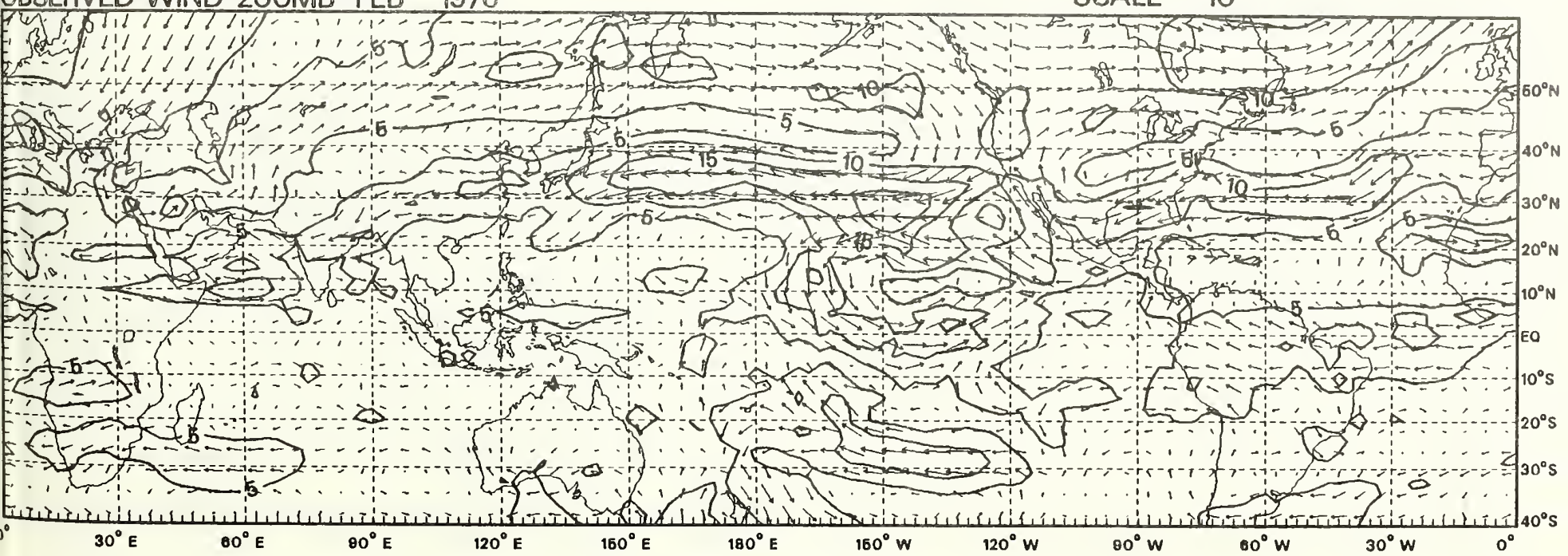
OBSERVED WIND 200MB FEB 1976
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40°S
30° E
60° E
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60° W
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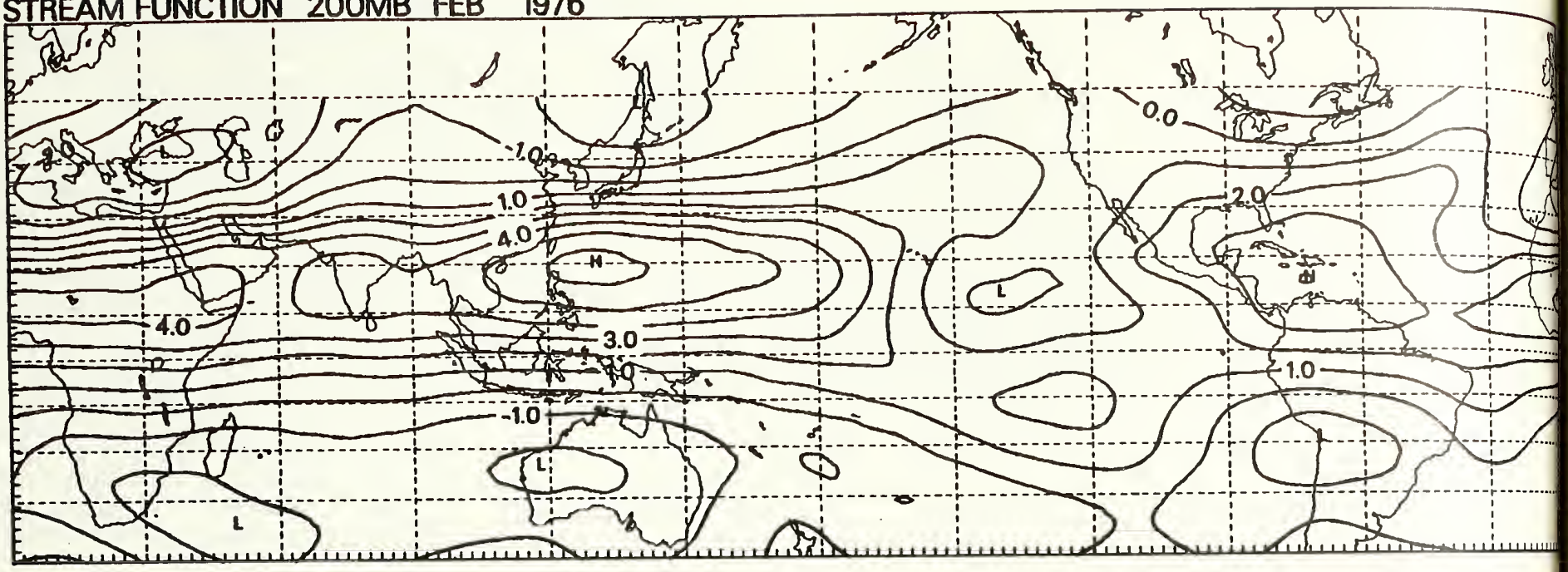
0°

STREAM FUNCTION 200MB FEB 1976



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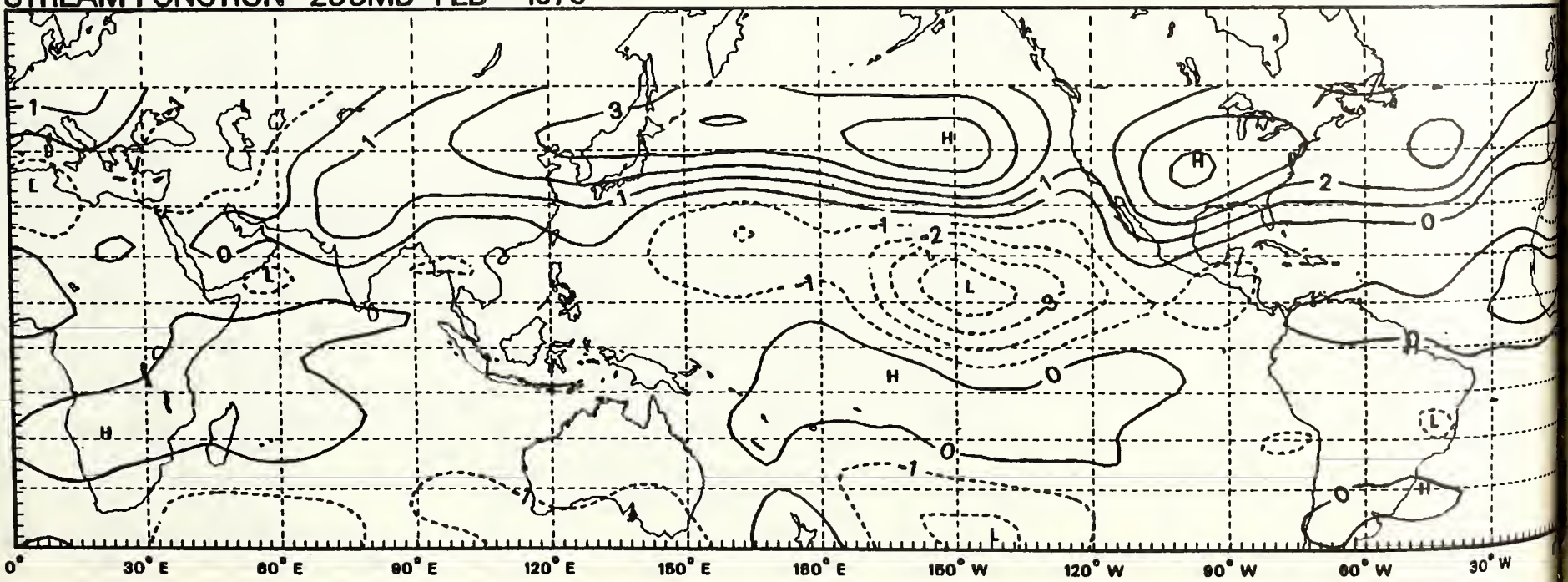
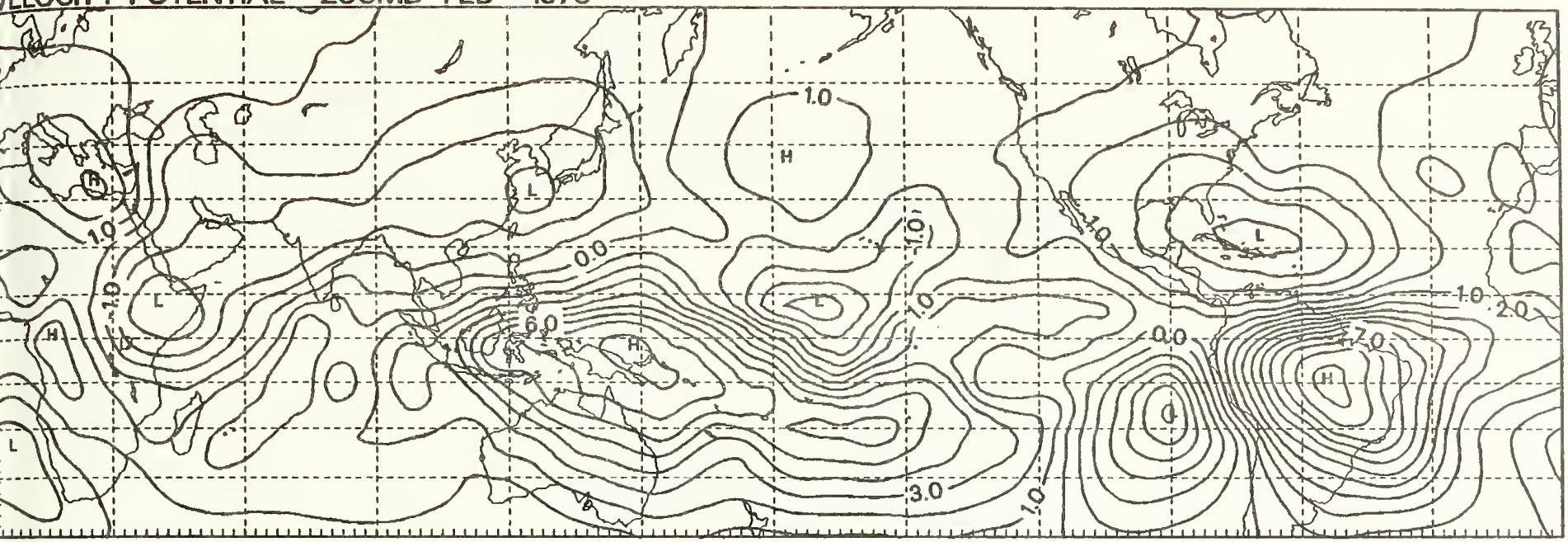


VELOCITY POTENTIAL 200MB FEB 1976



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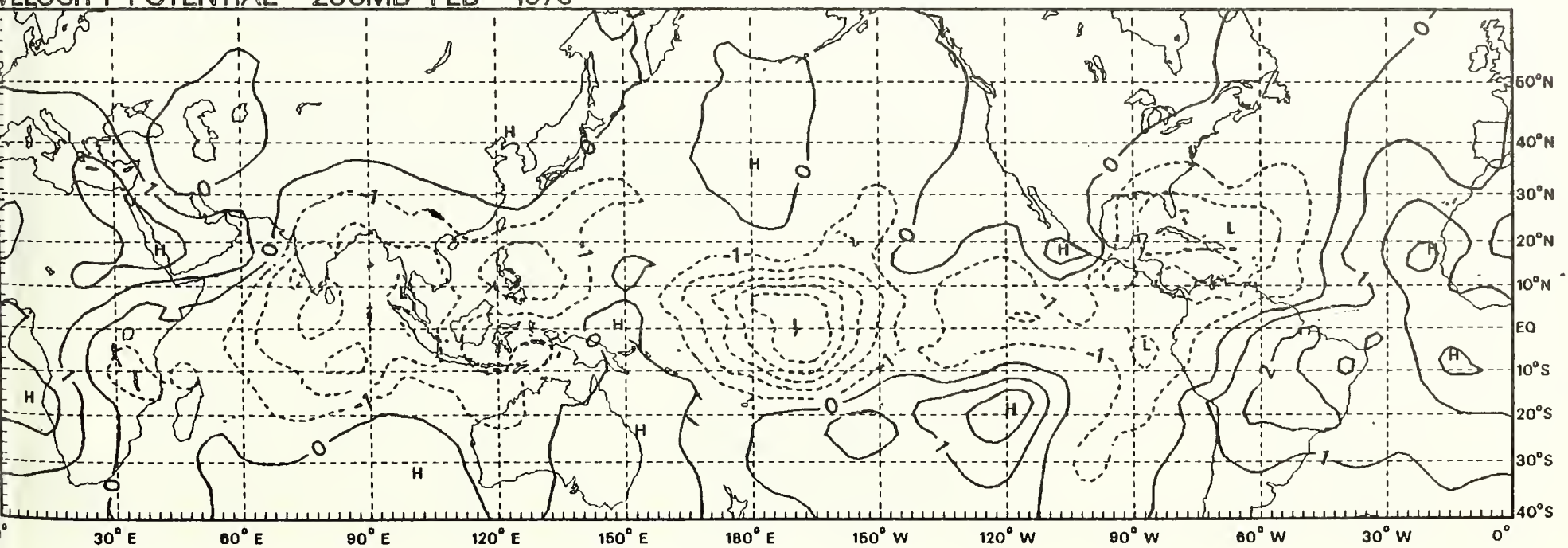

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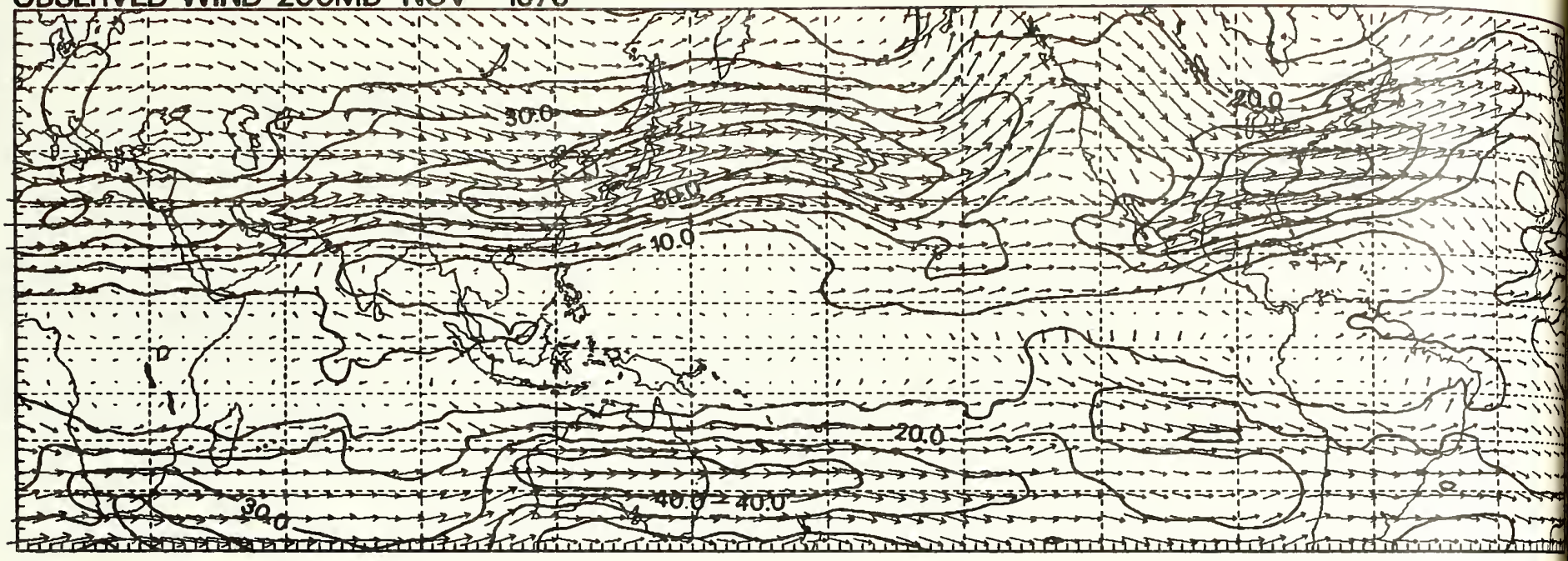

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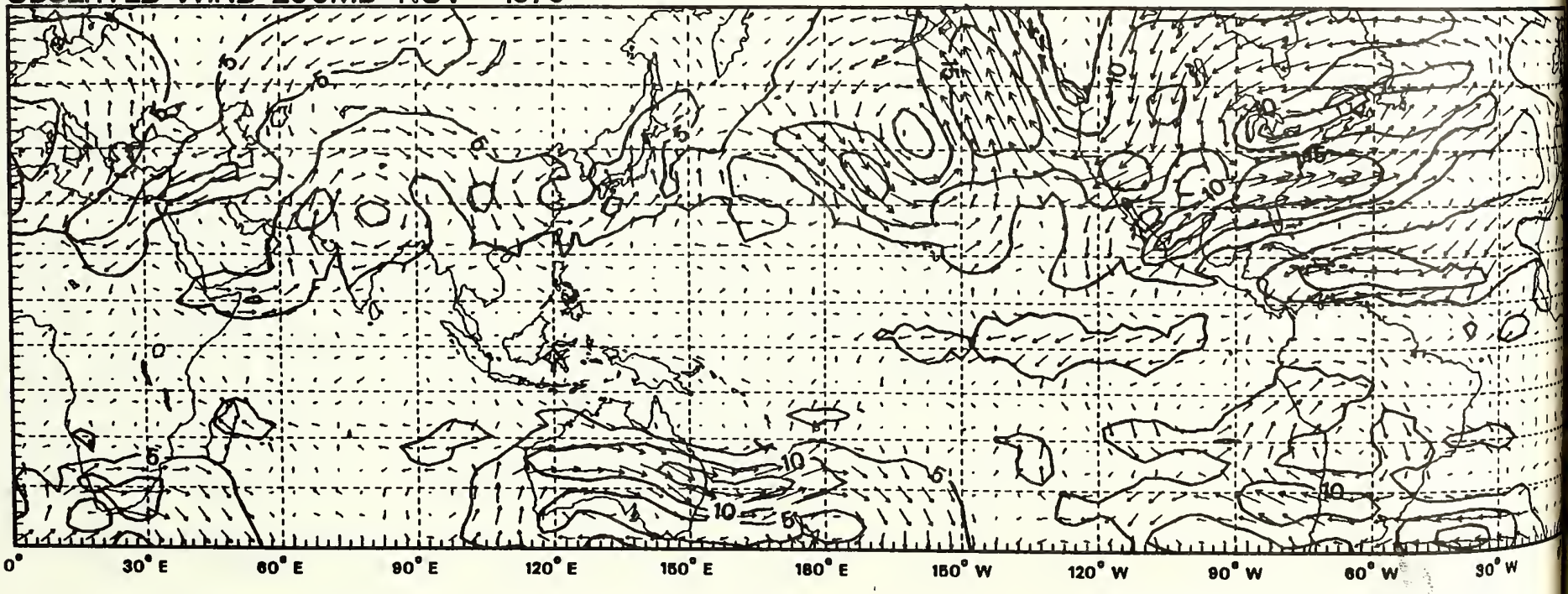
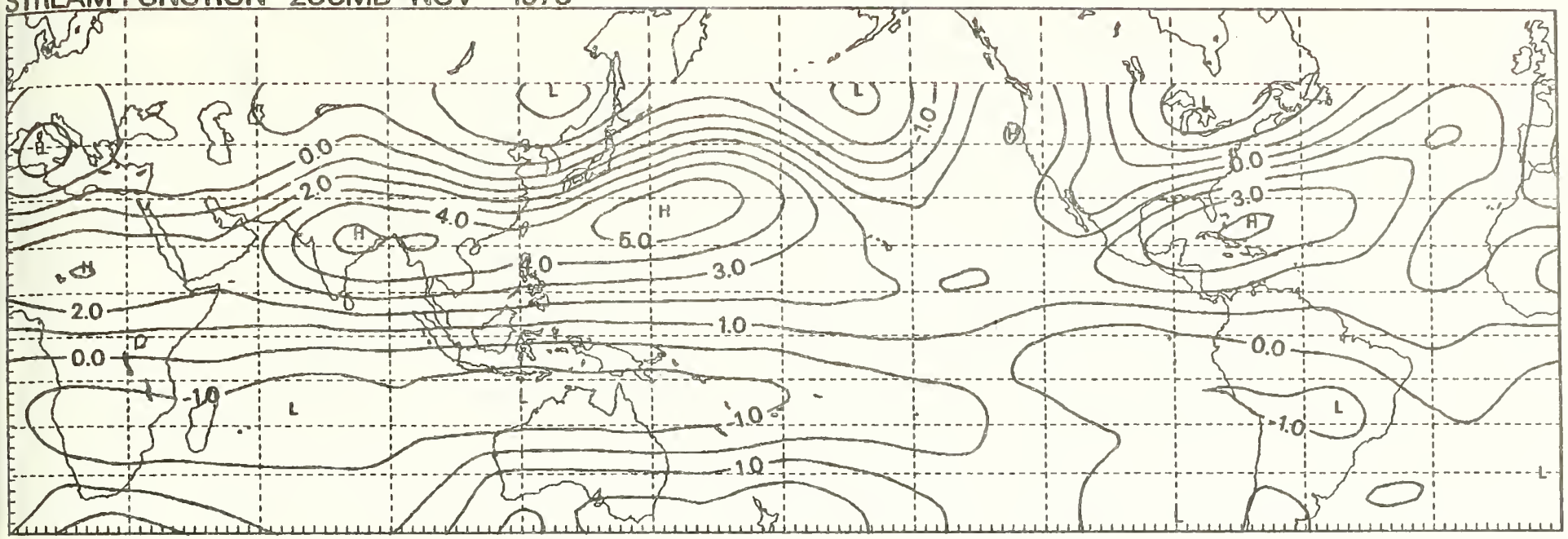


STREAM FUNCTION 200MB NOV 1976



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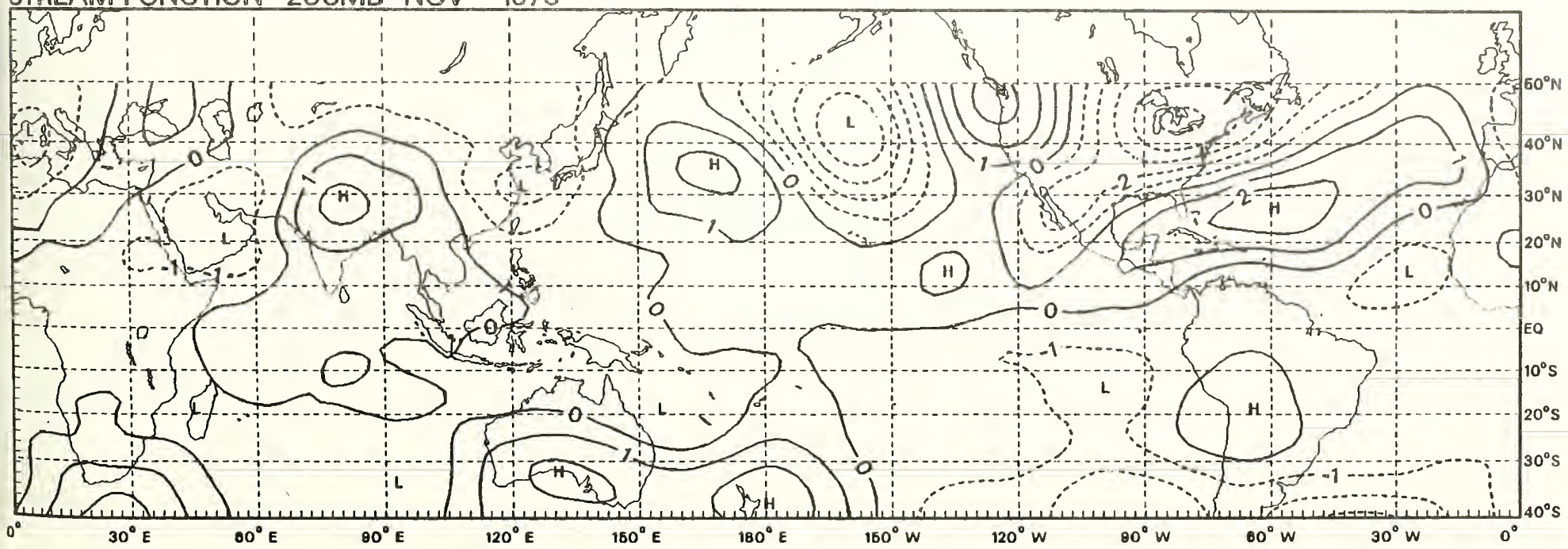
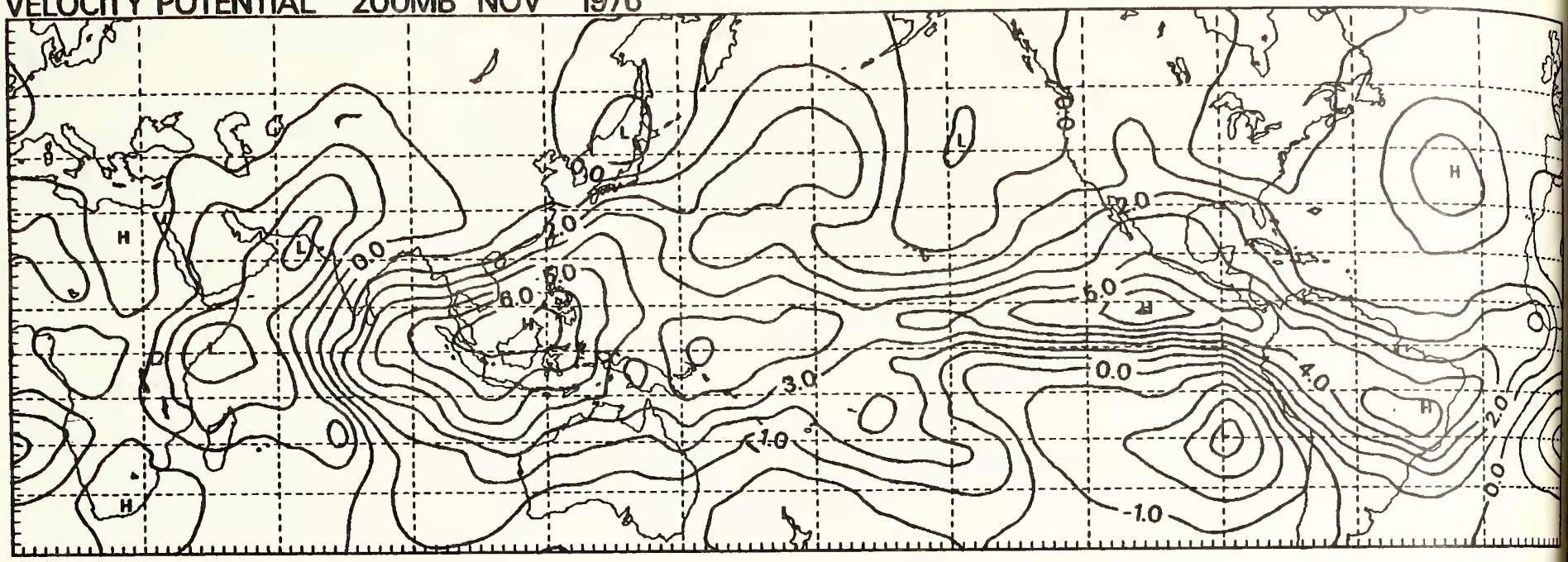
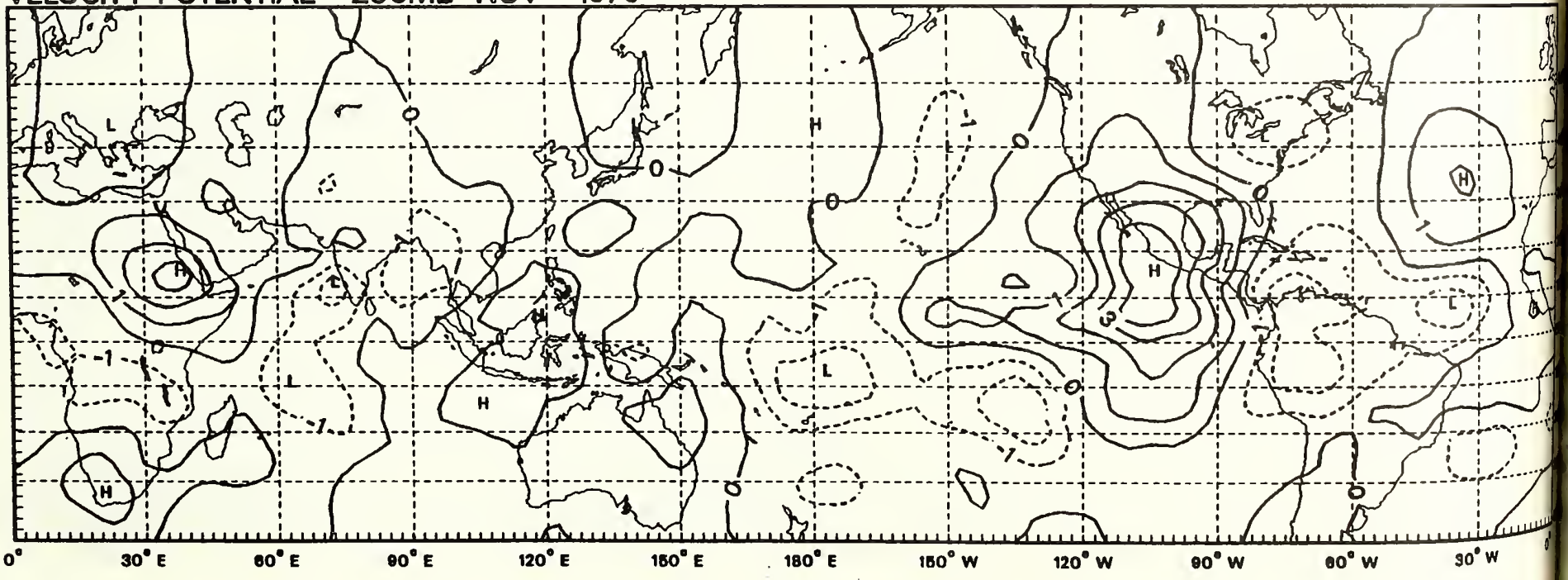
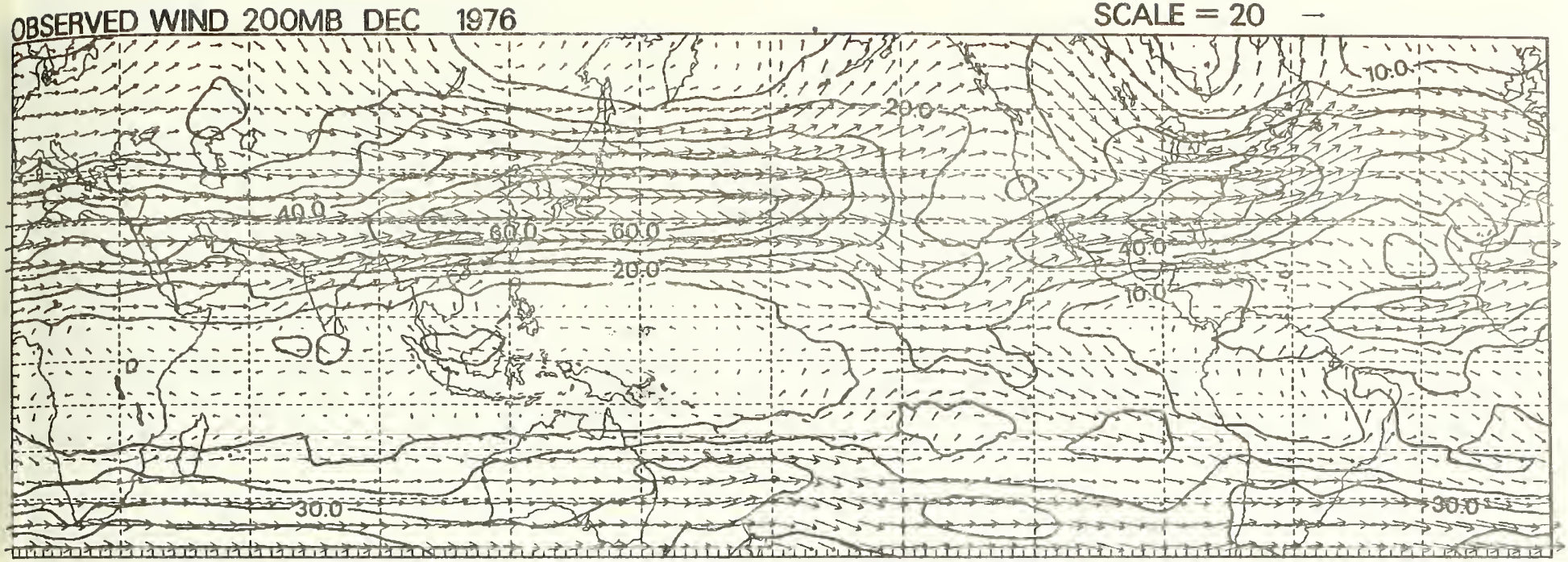


VELOCITY POTENTIAL 200MB NOV 1976



VELOCITY POTENTIAL 200MB NOV 1976

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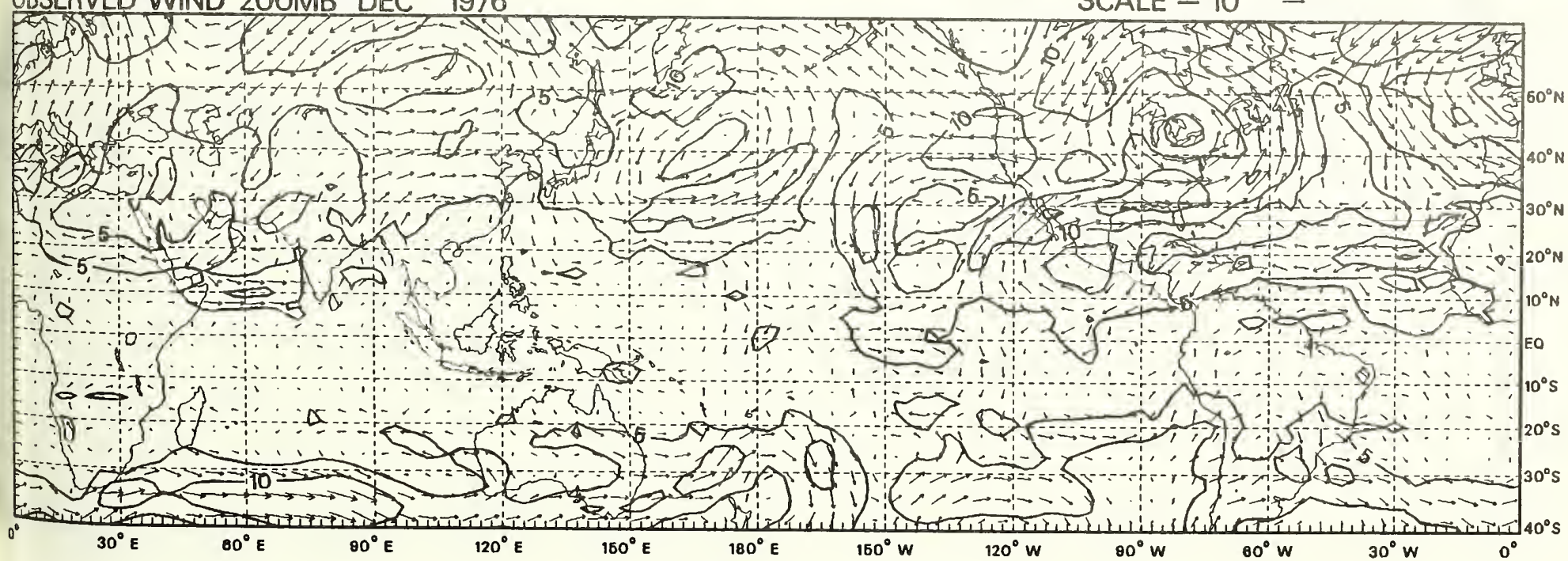
OBSERVED WIND 200MB DEC 1976
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EQ
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40°S
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30° E
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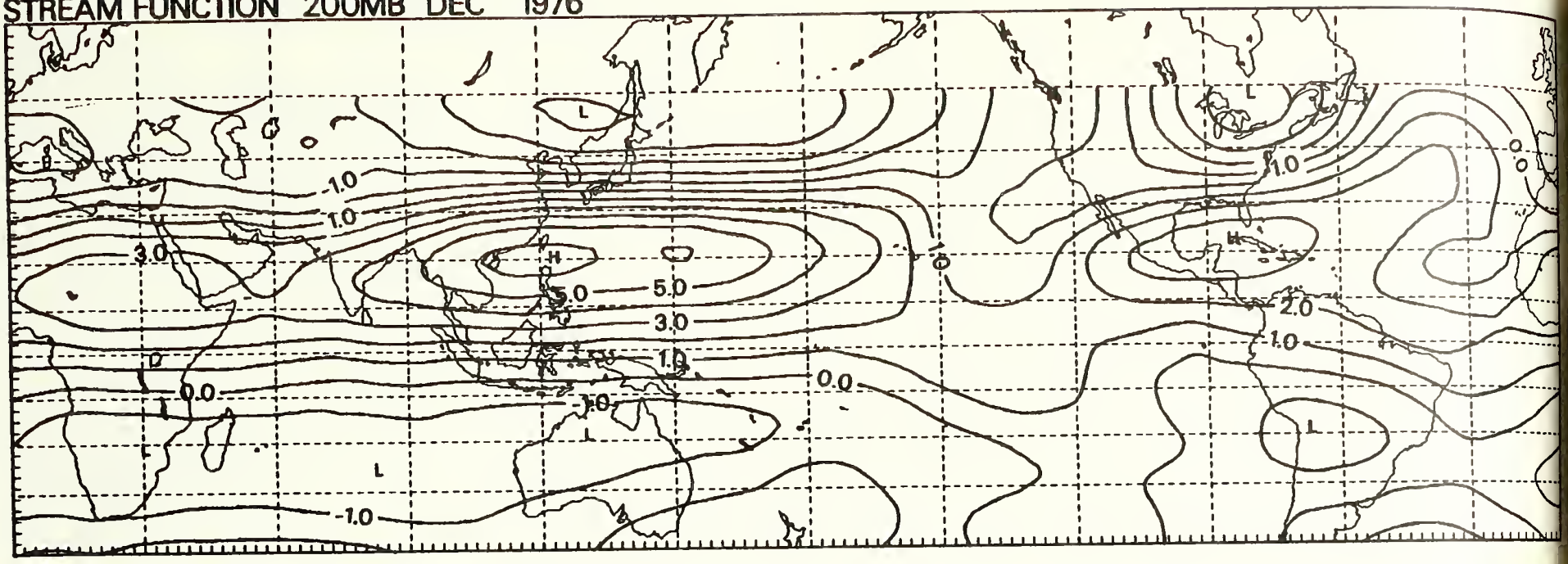
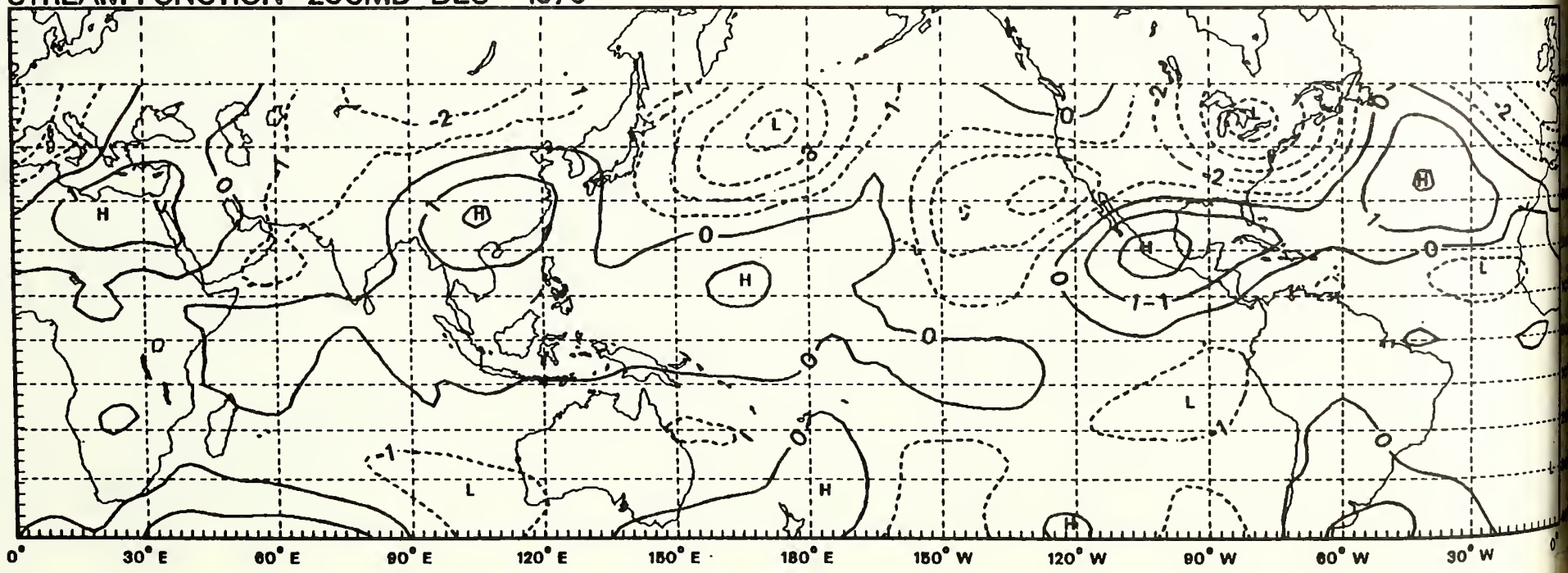
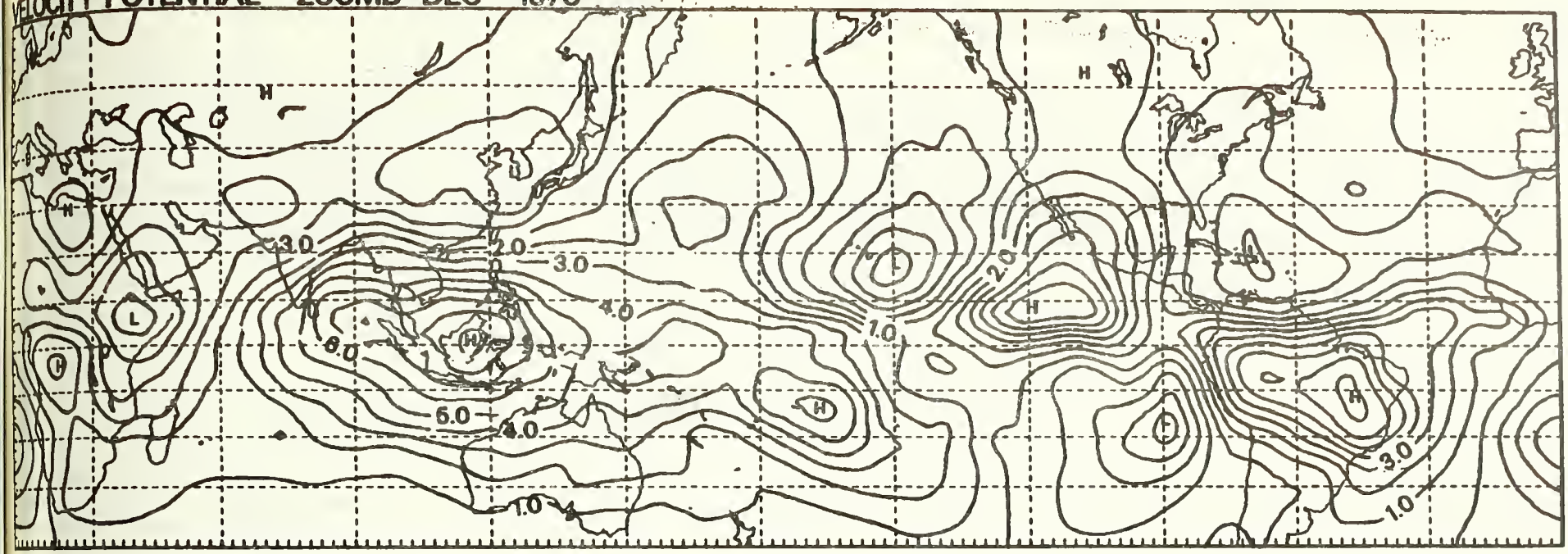
STREAM FUNCTION 200MB DEC 1976



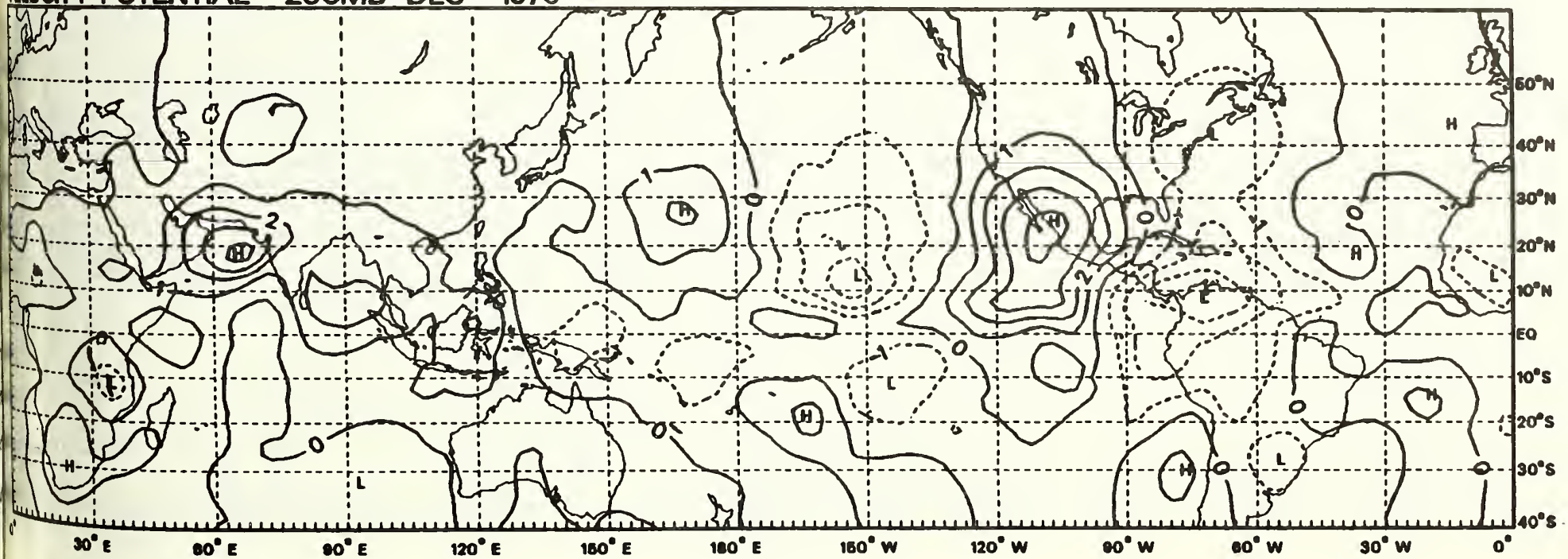
STREAM FUNCTION 200MB DEC 1976



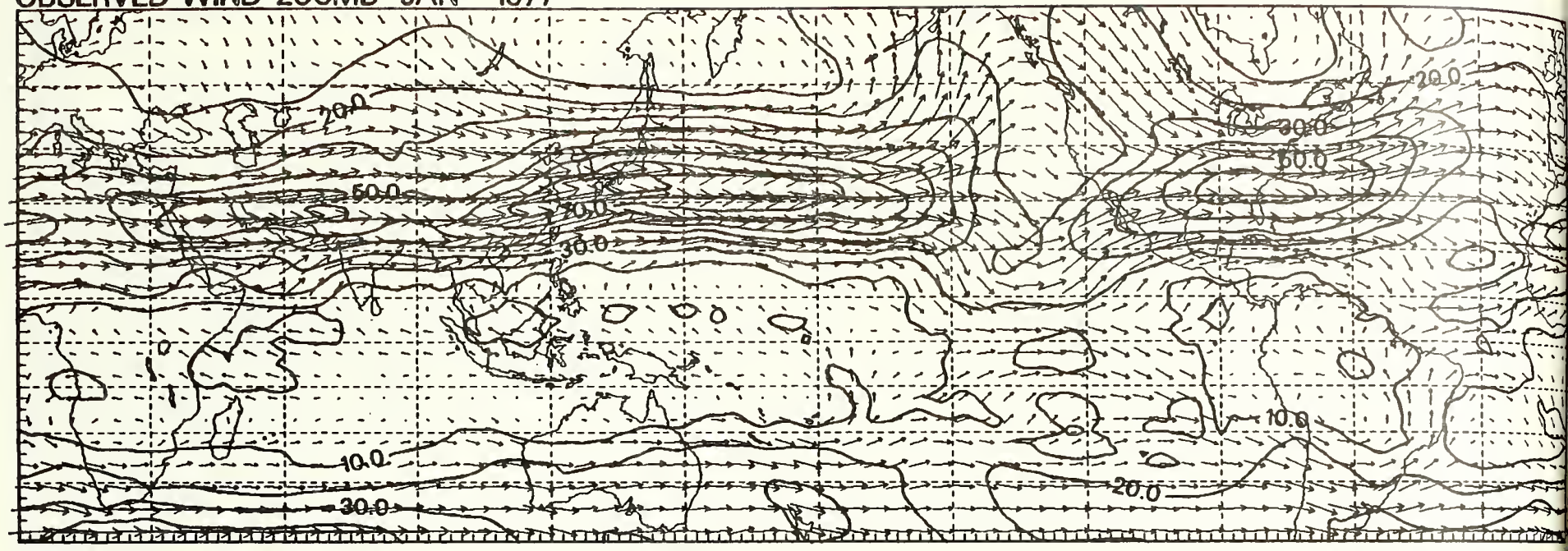
VELOCITY POTENTIAL 200MB DEC 1976



VELOCITY POTENTIAL 200MB DEC 1976



OBSERVED WIND 200MB JAN 1977 SCALE = 20



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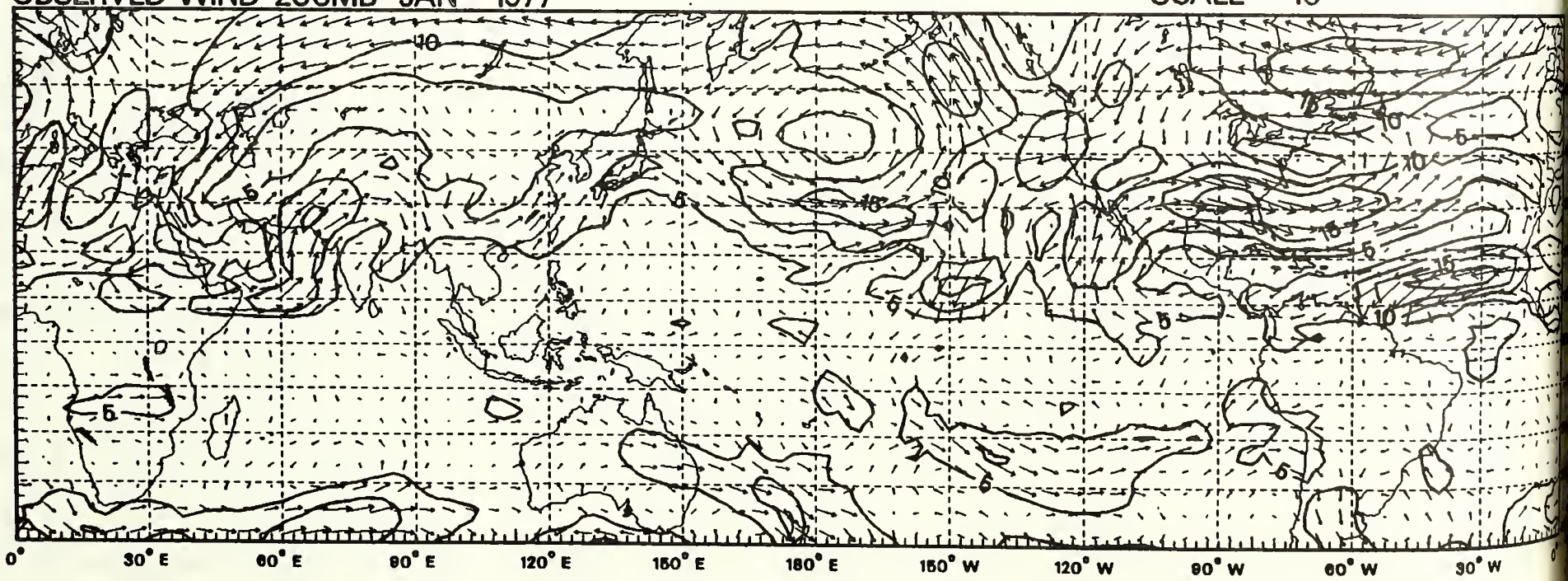
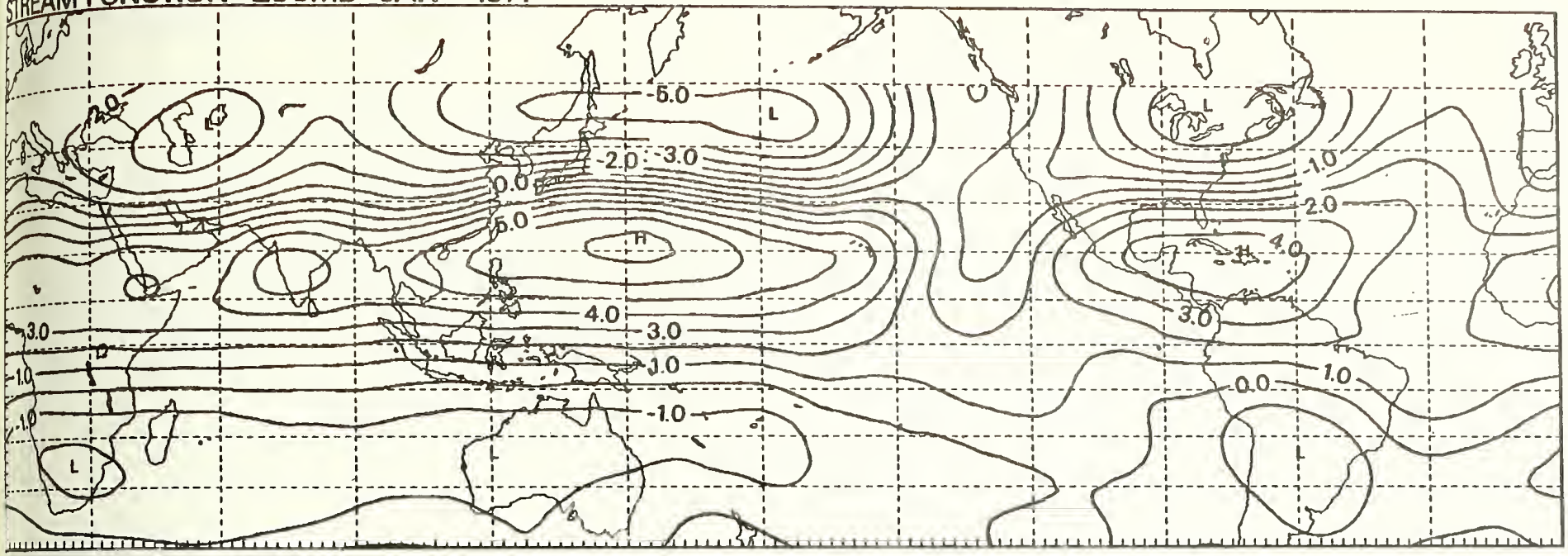


STREAM FUNCTION 200MB JAN 1977



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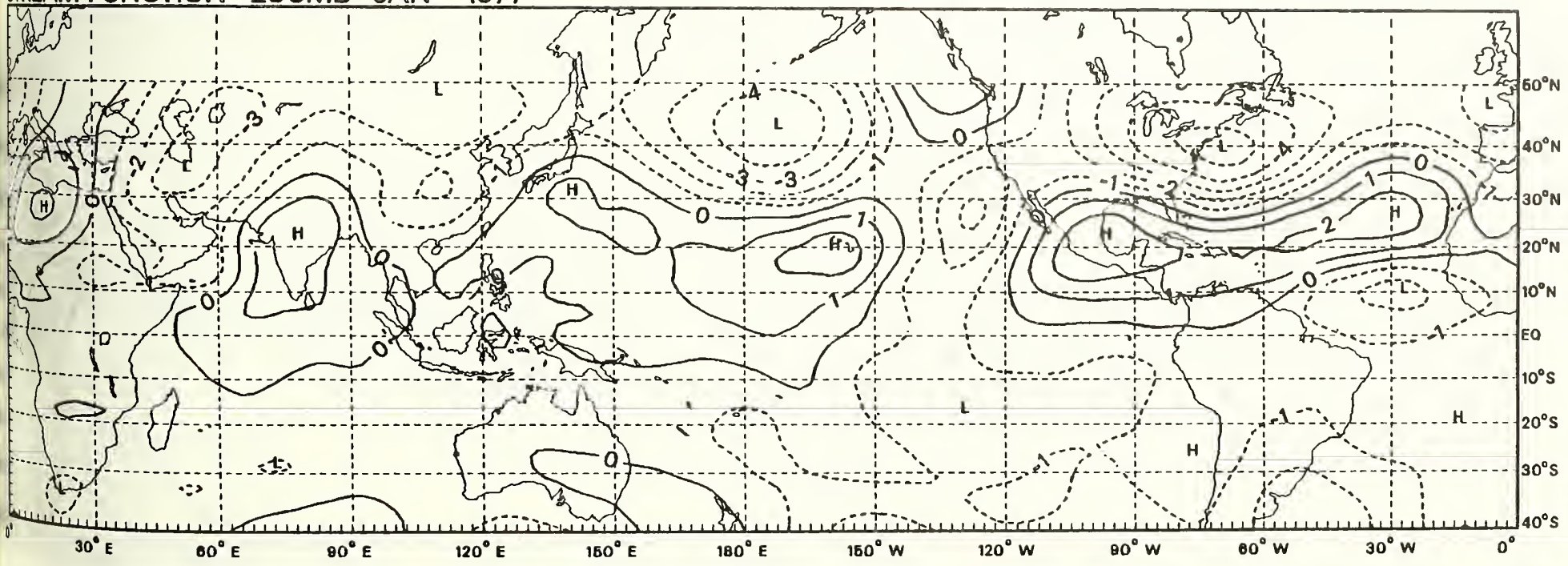
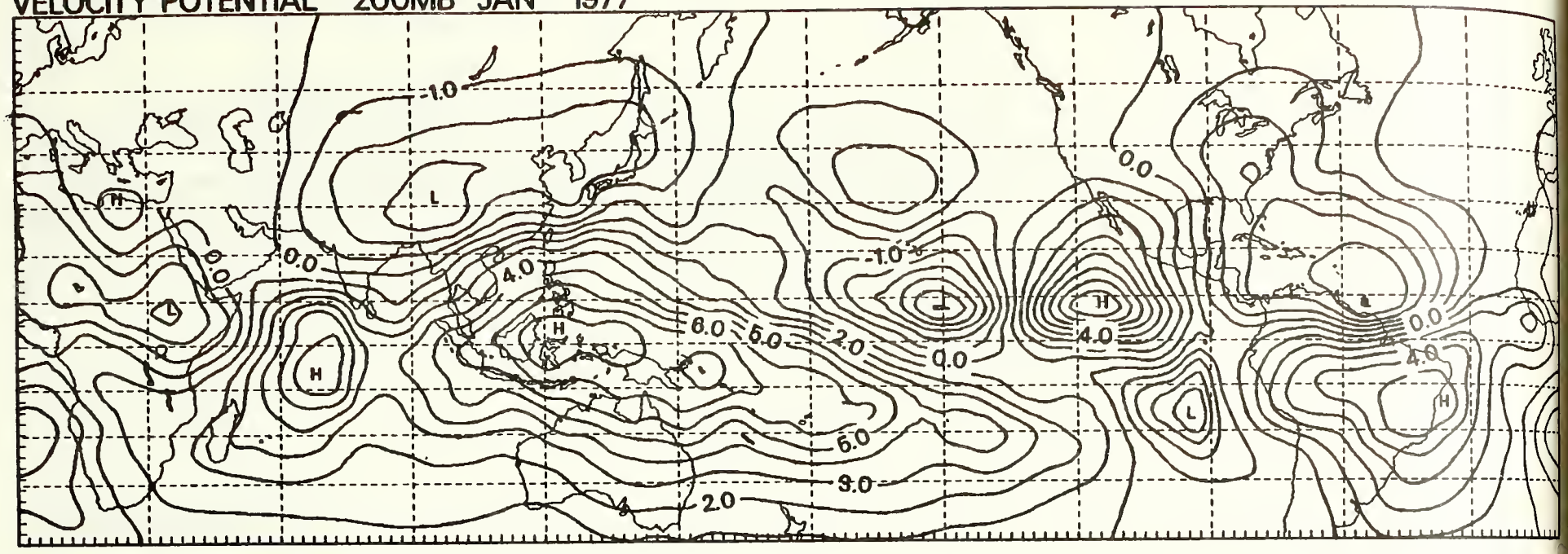


VELOCITY POTENTIAL 200MB JAN 1977



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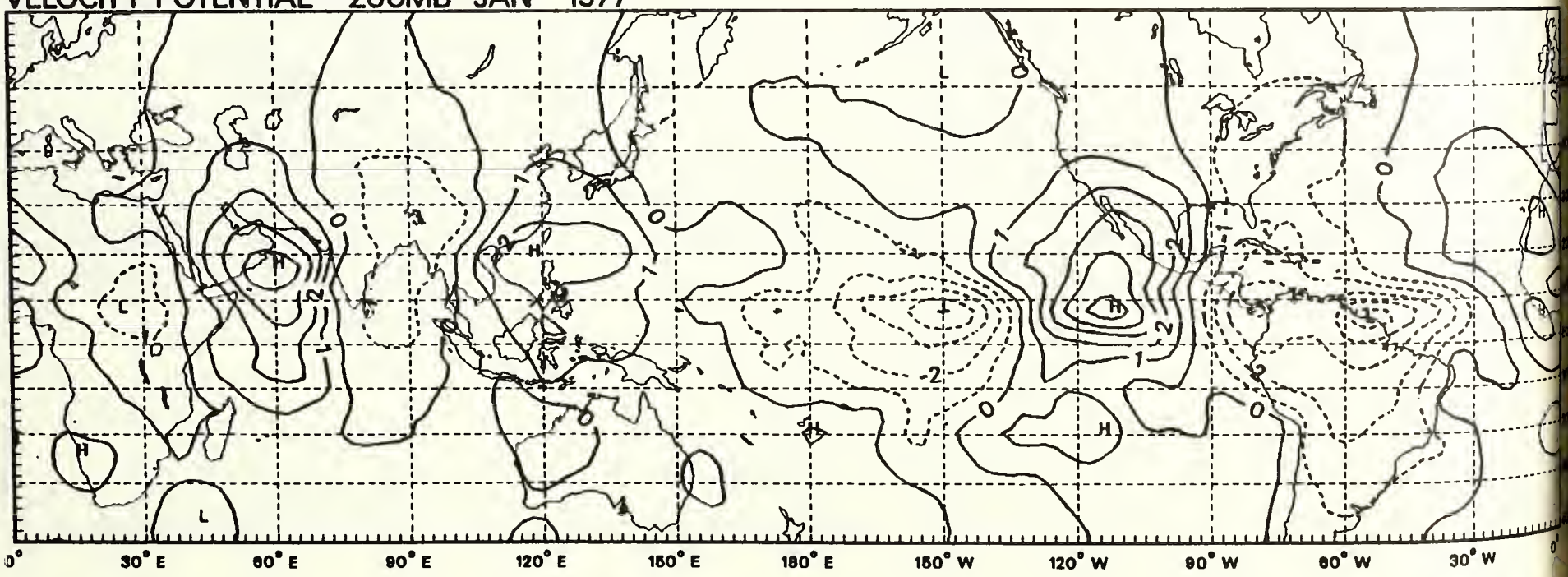

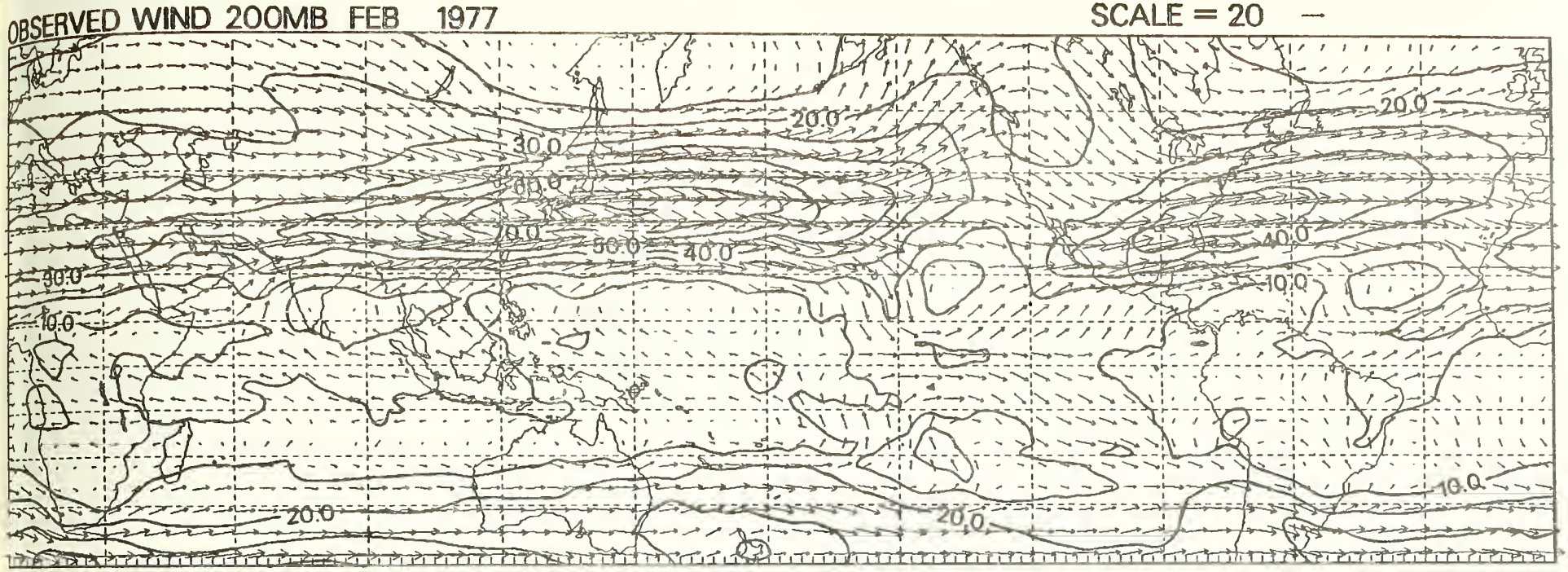
OBSERVED WIND 200MB FEB 1977
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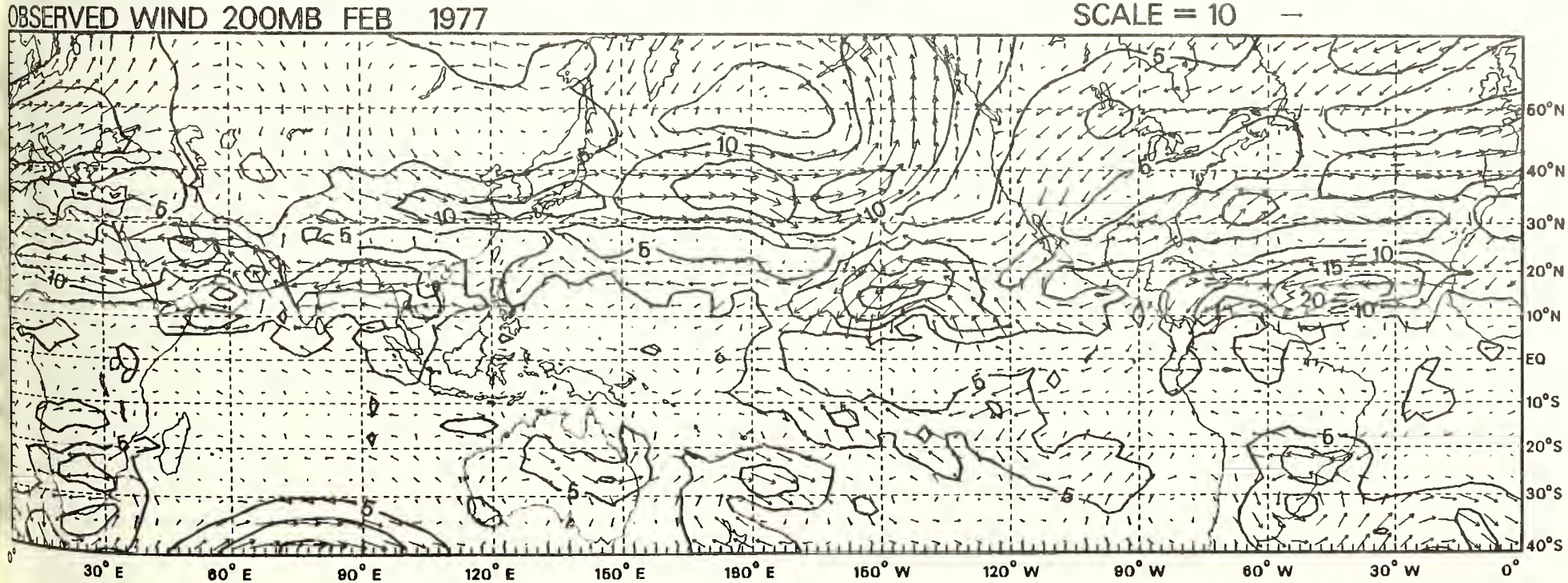
OBSERVED WIND 200MB FEB 1977
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30°S
40°S
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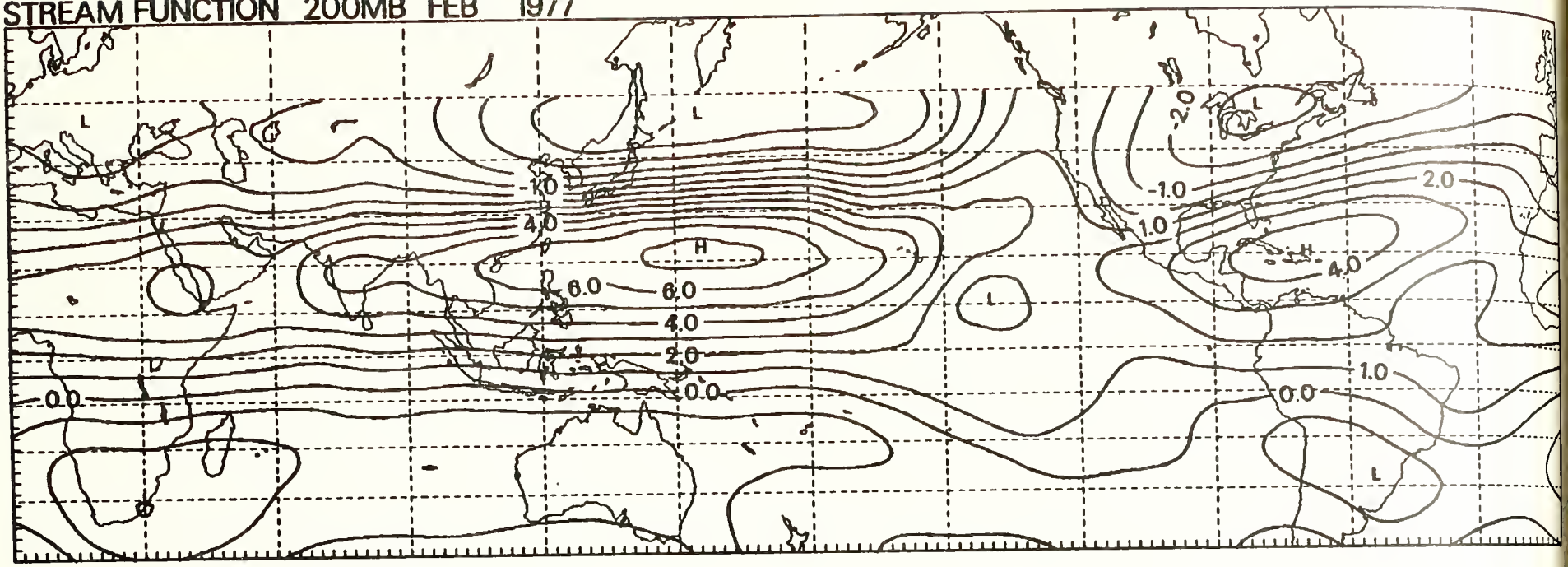
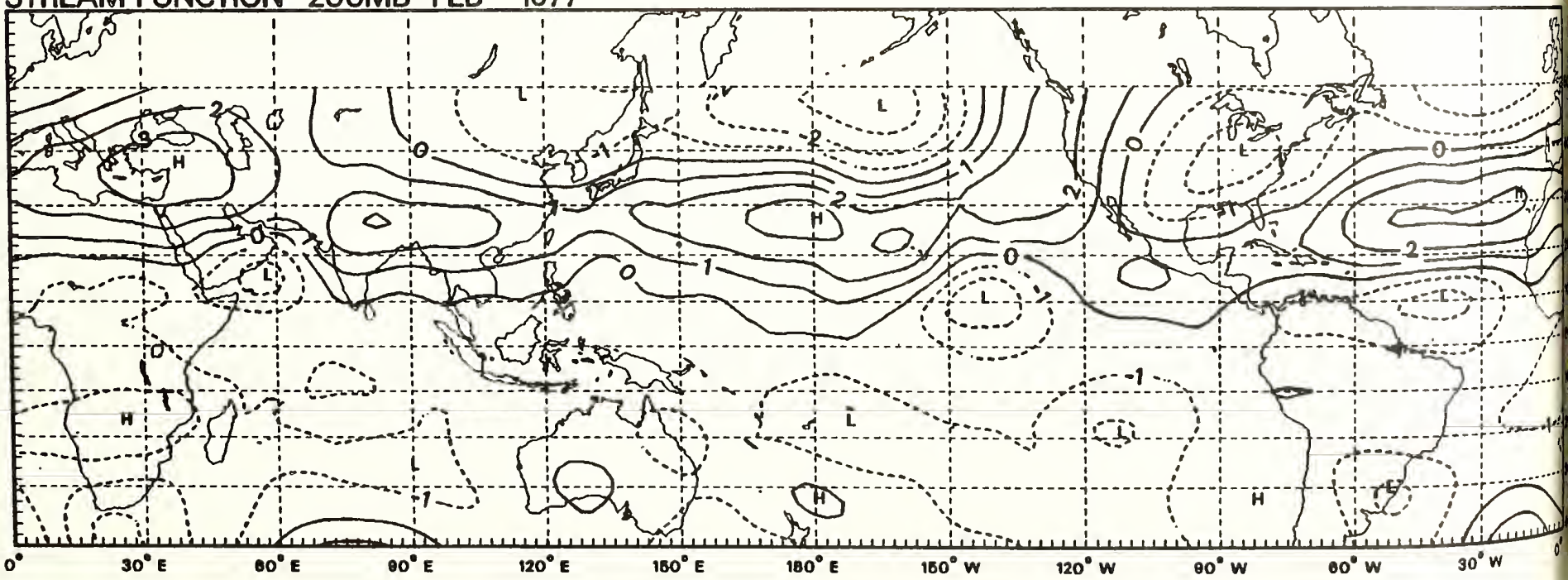
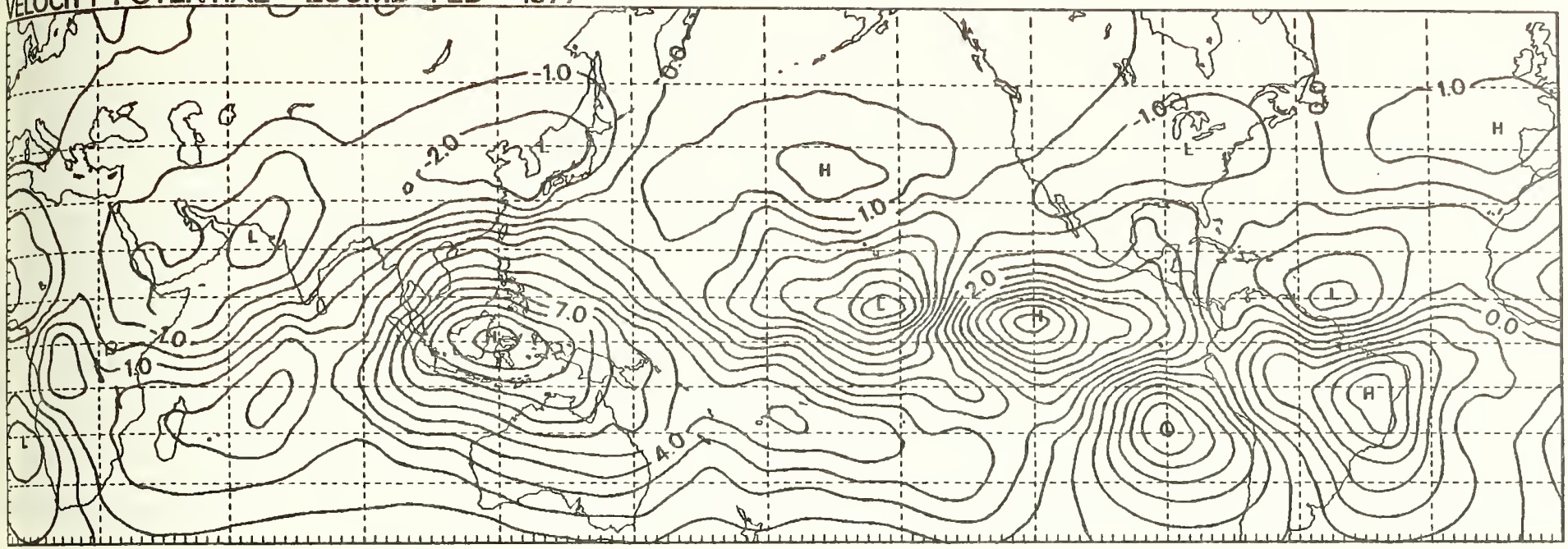
STREAM FUNCTION 200MB FEB 1977



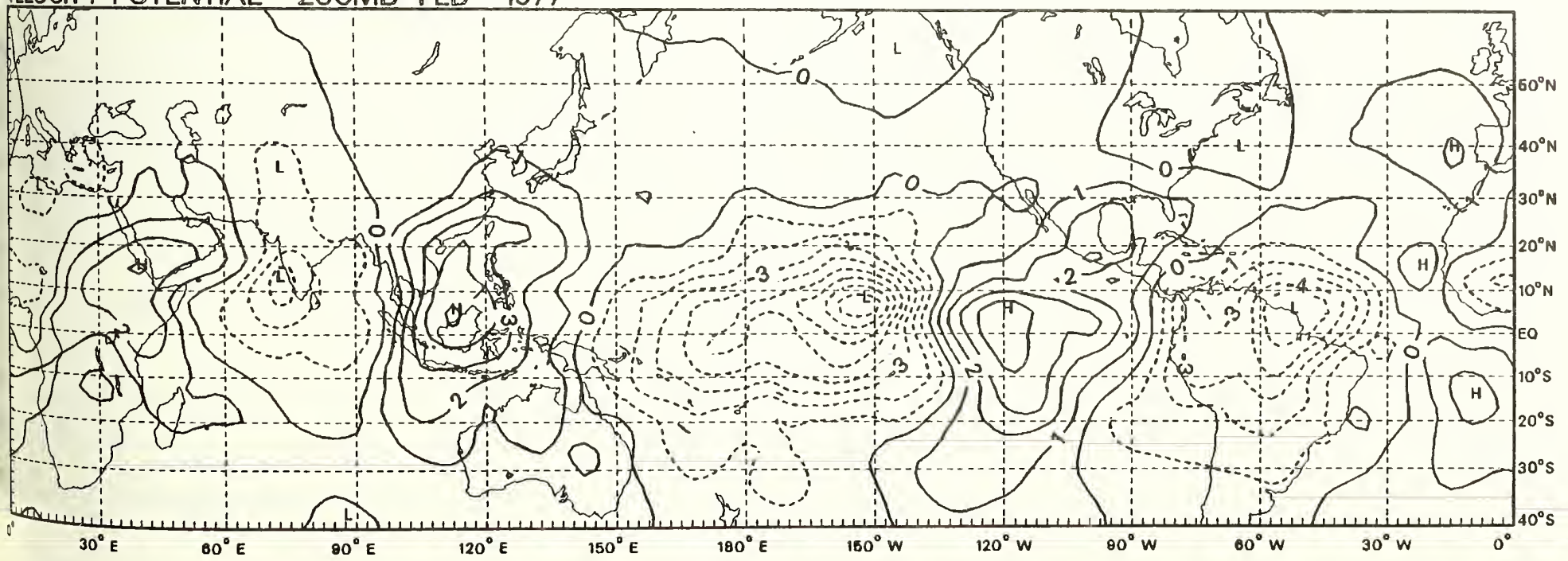
STREAM FUNCTION 200MB FEB 1977



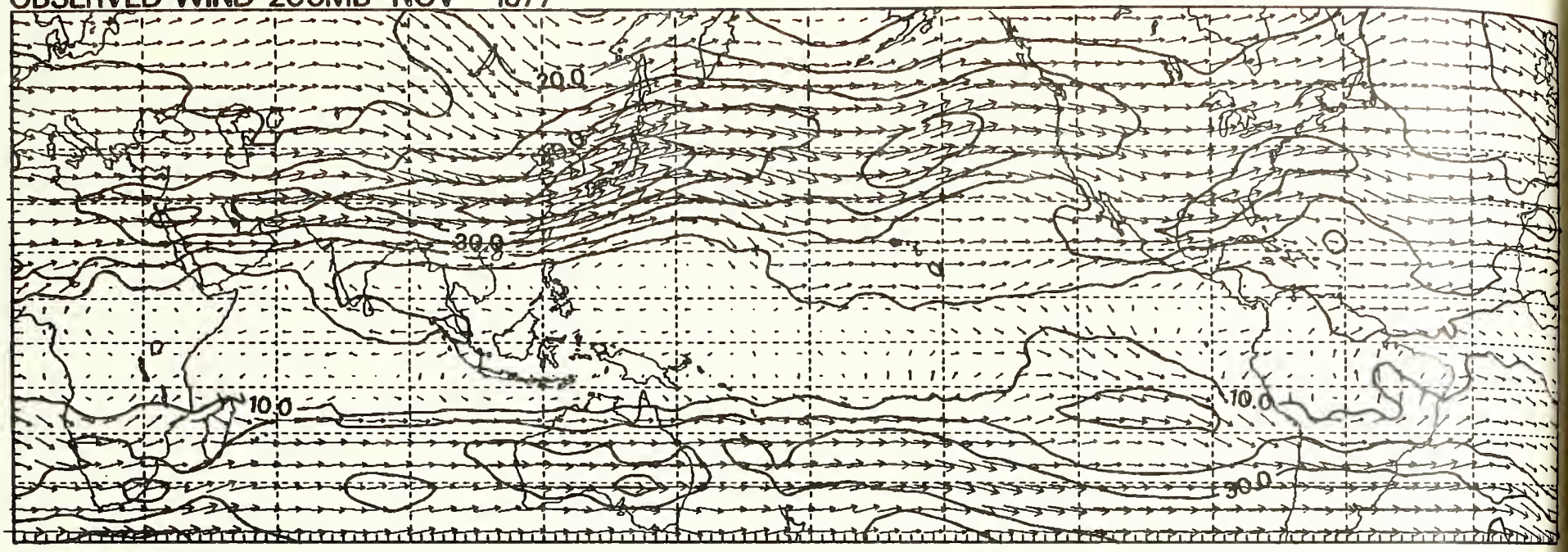
VELOCITY POTENTIAL 200MB FEB 1977



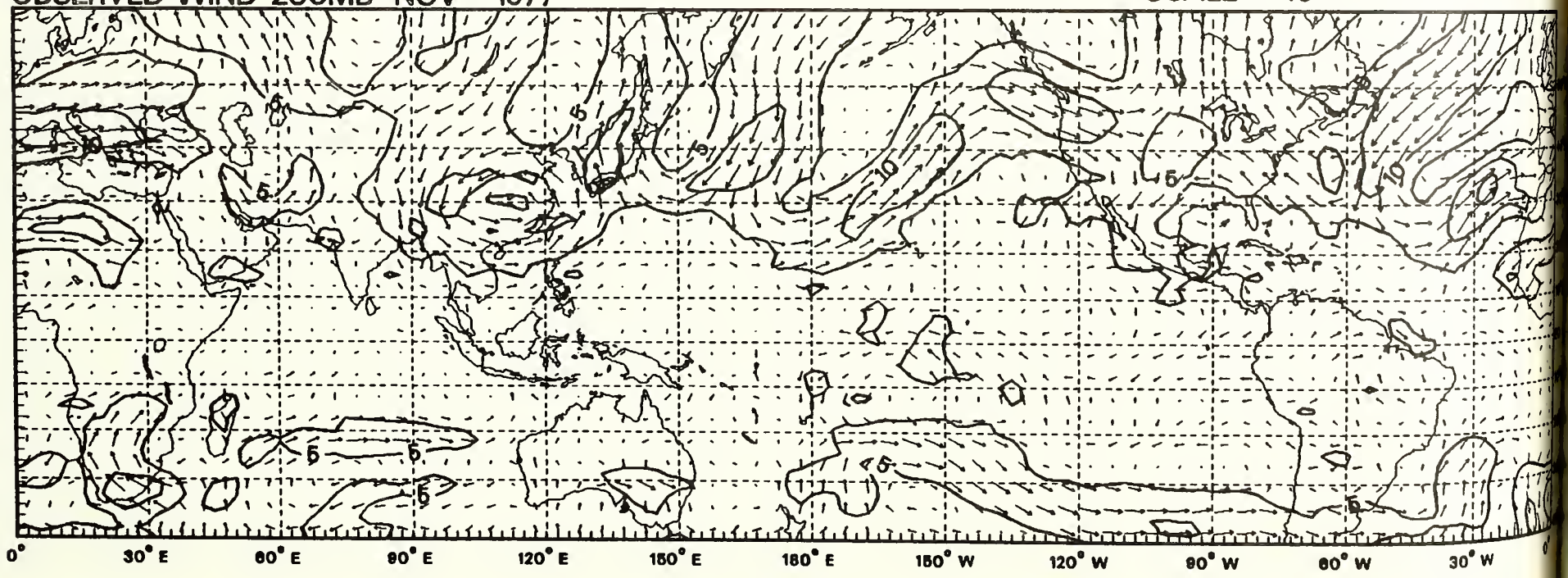
VELOCITY POTENTIAL 200MB FEB 1977



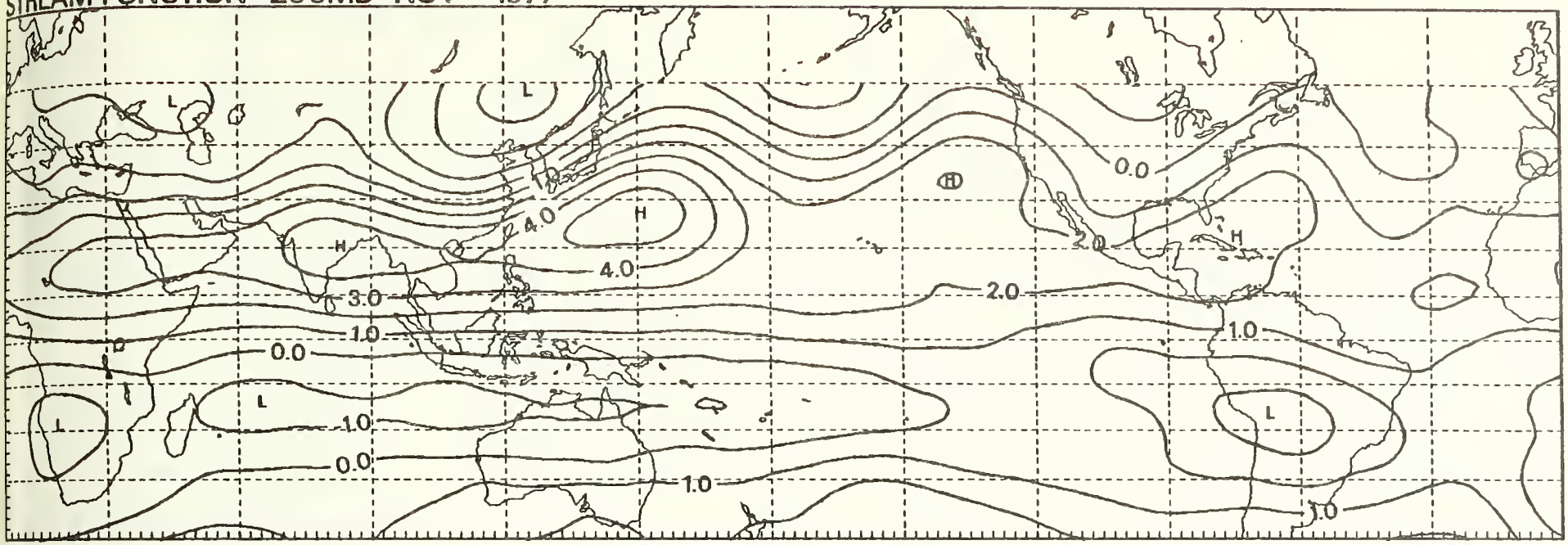
OBSERVED WIND 200MB NOV 1977 SCALE = 20



OBSERVED WIND 200MB NOV 1977 SCALE = 10



STREAM FUNCTION 200MB NOV 1977



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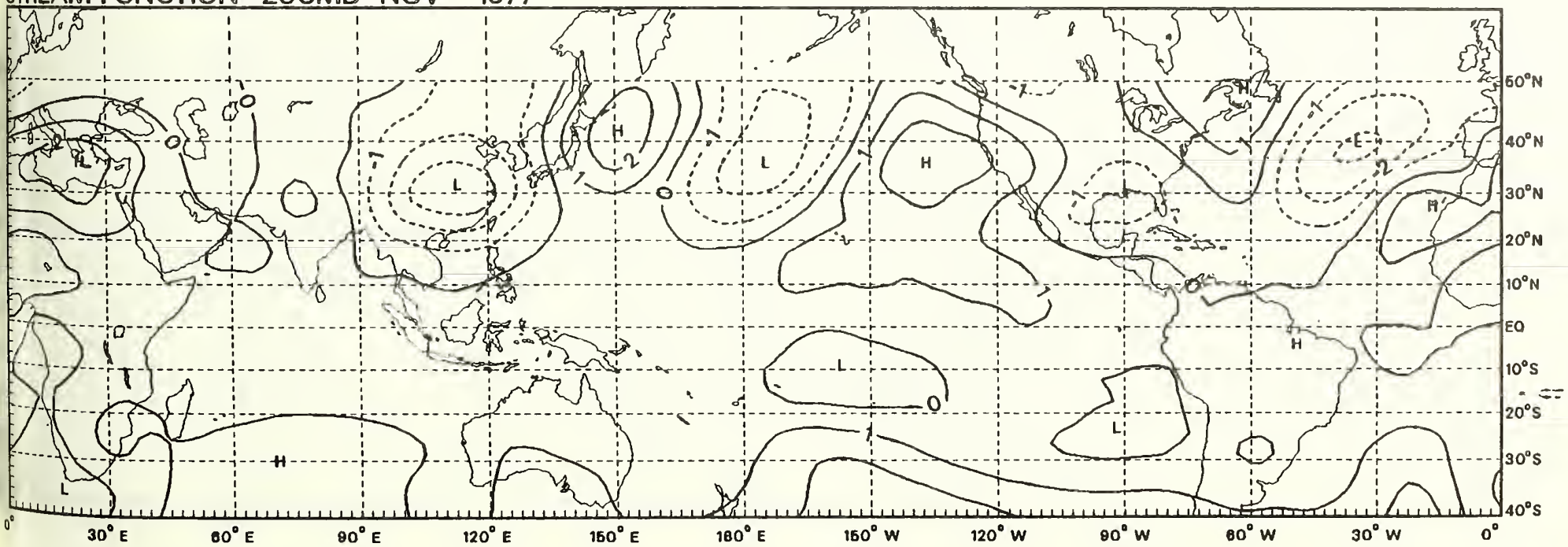

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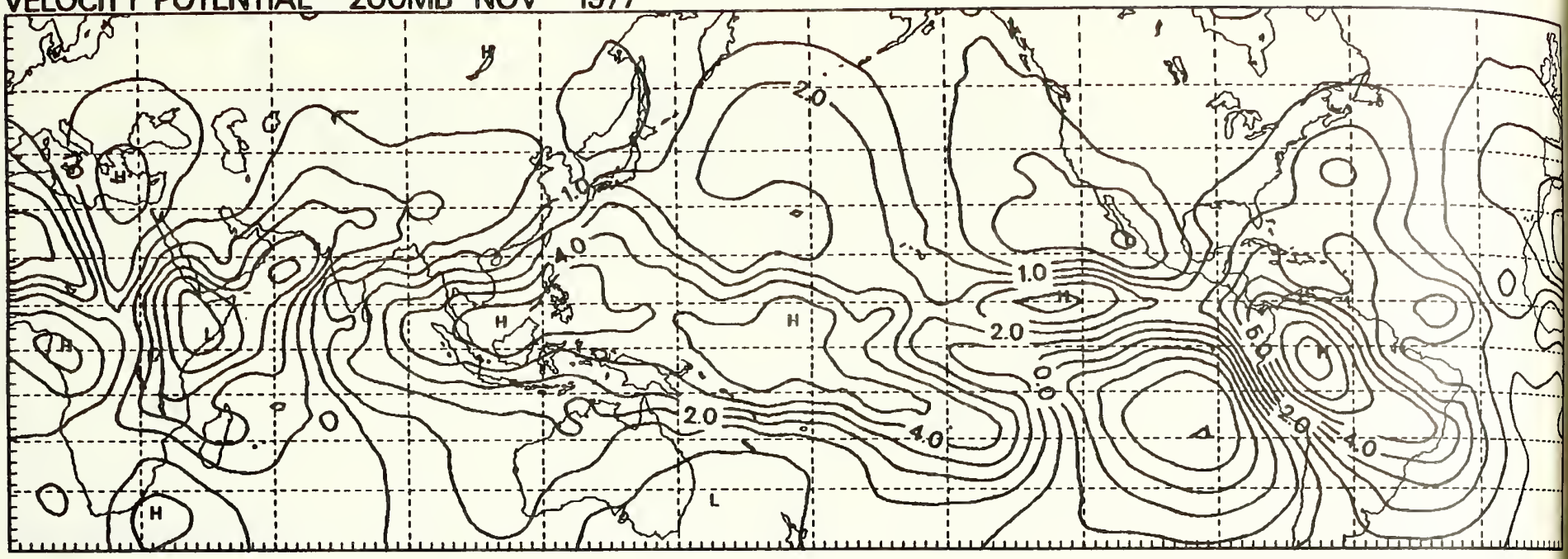

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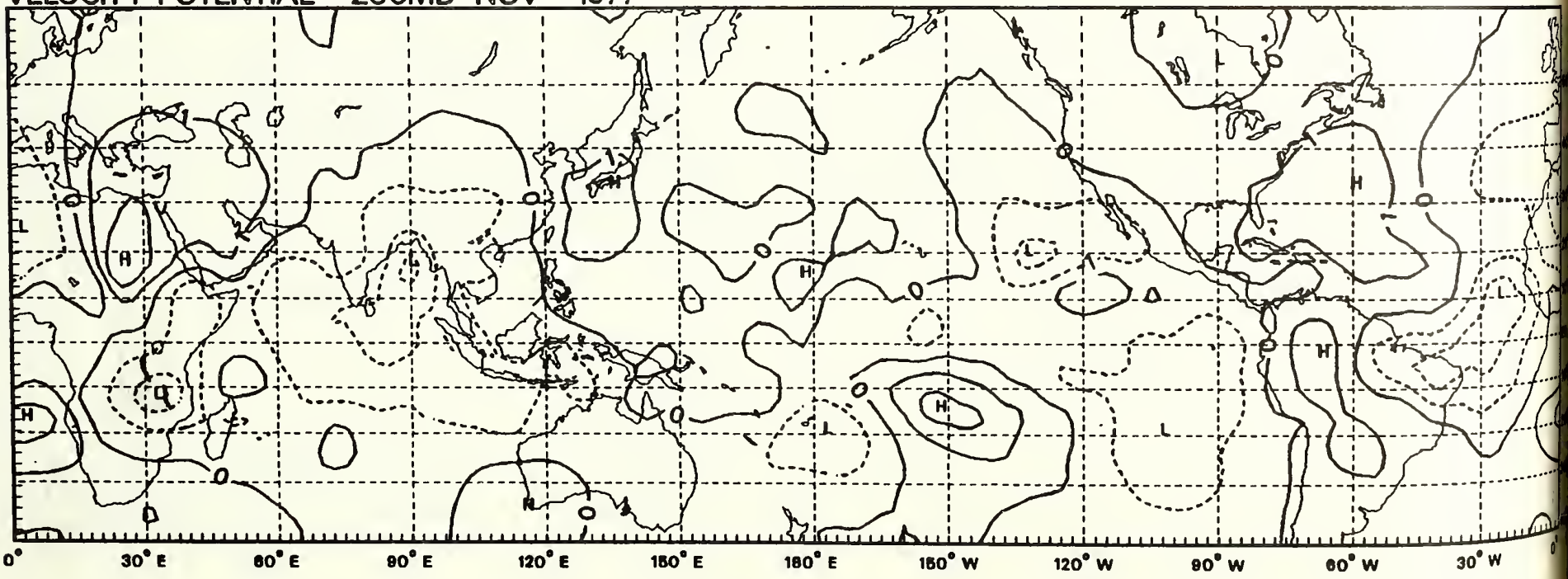

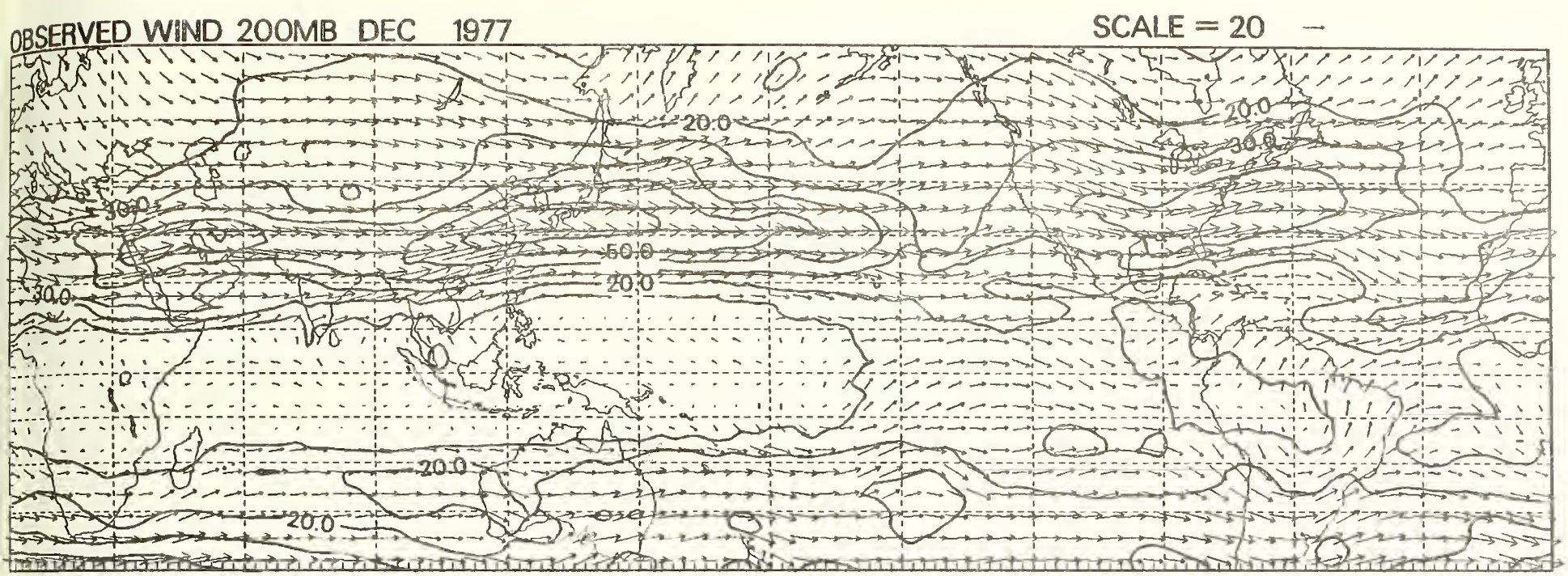
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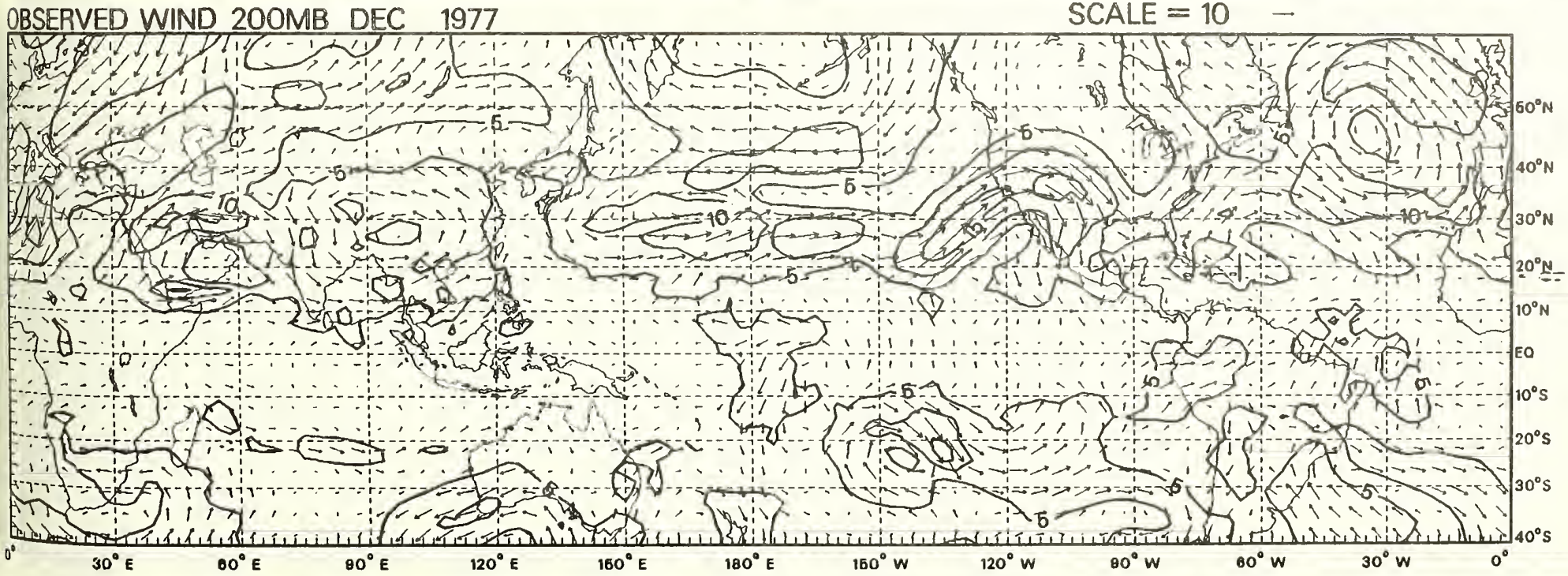
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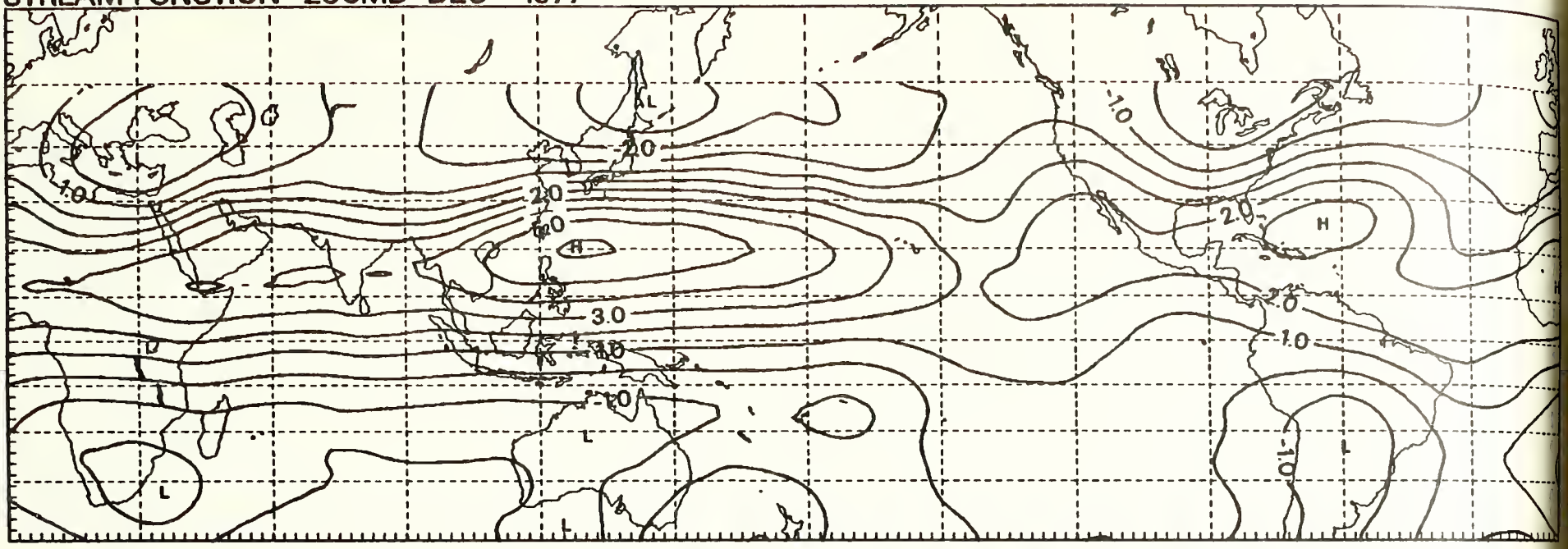

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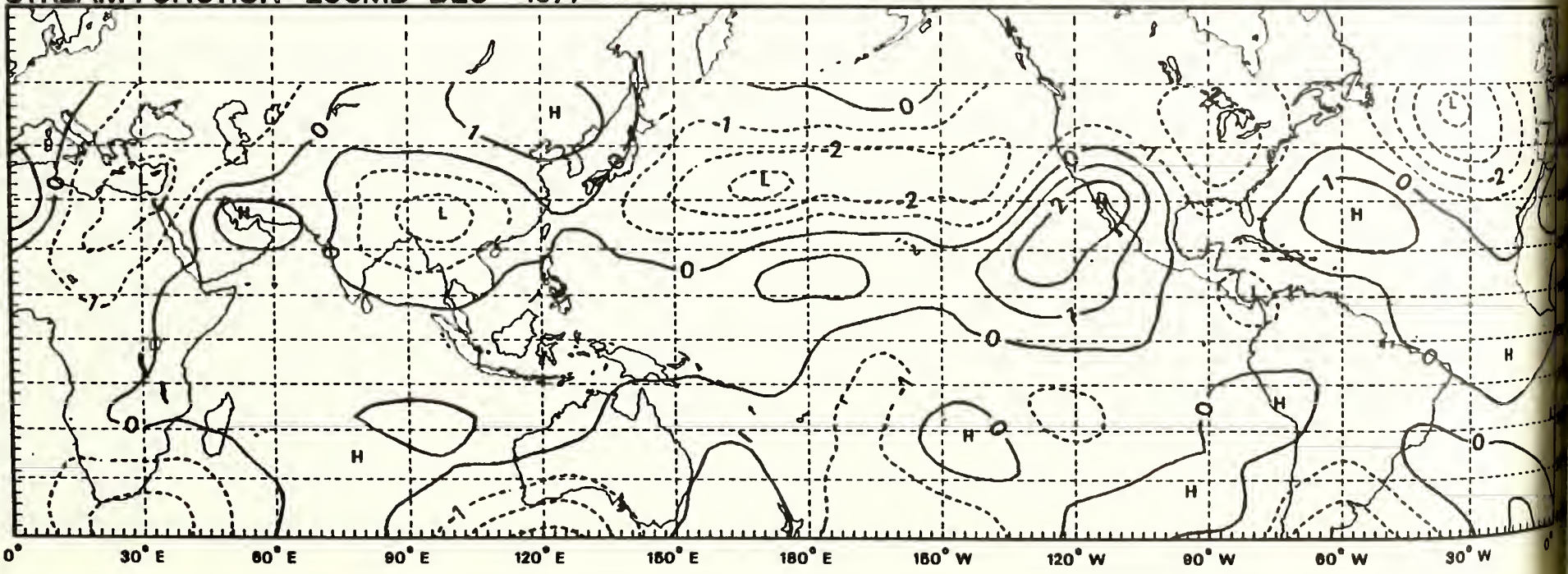

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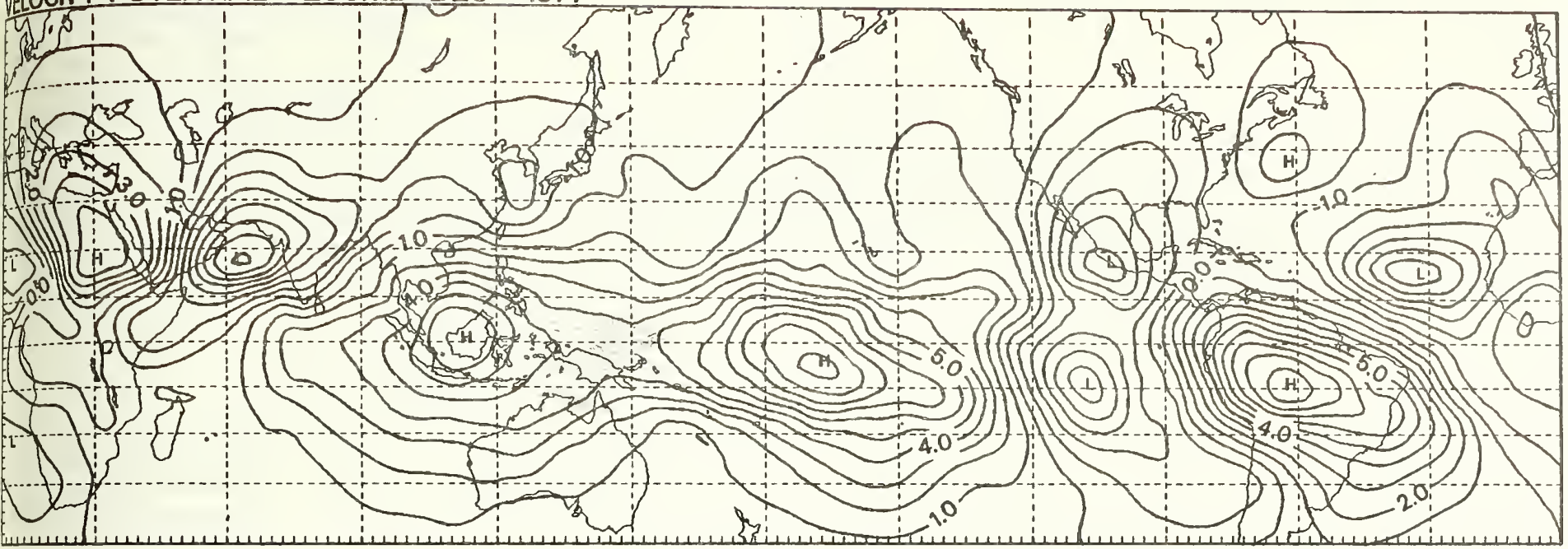

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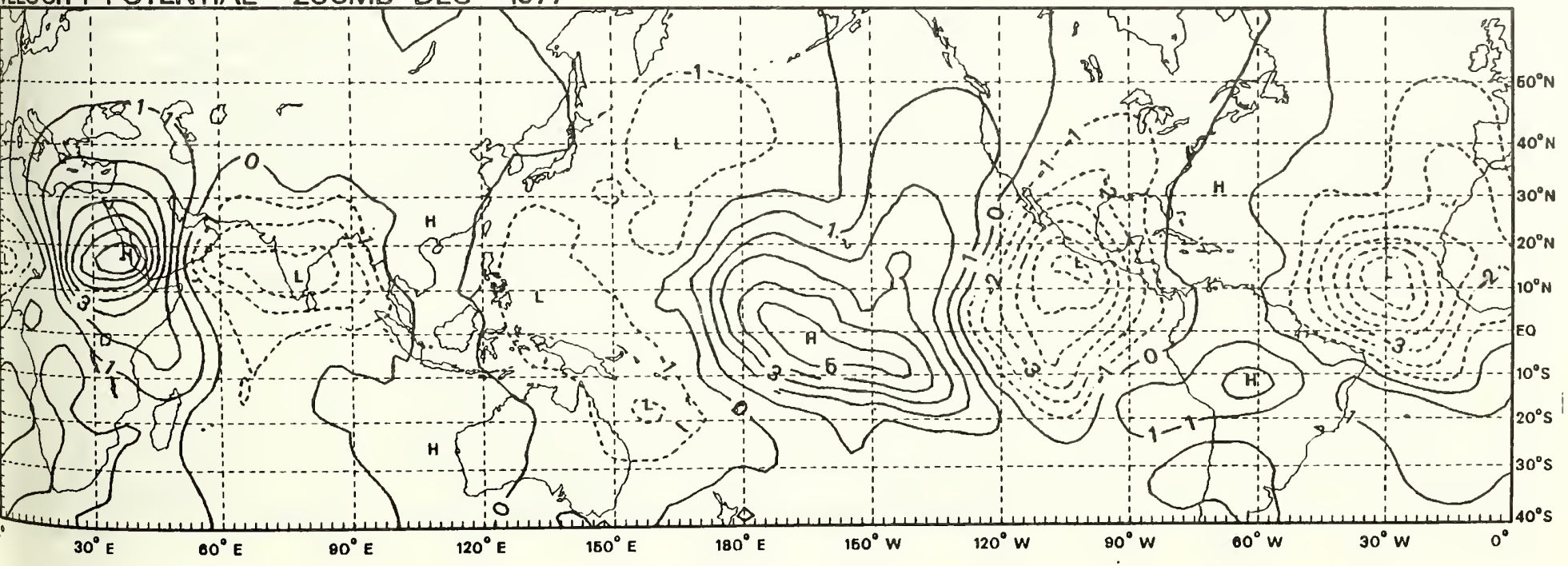

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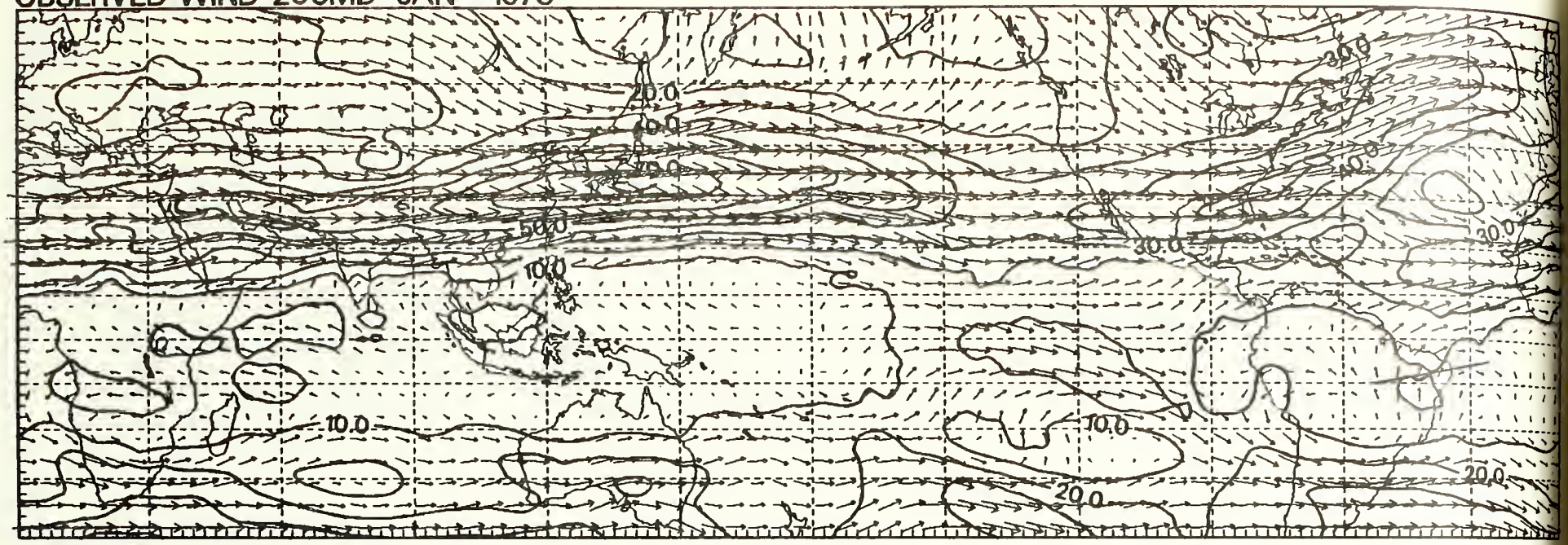

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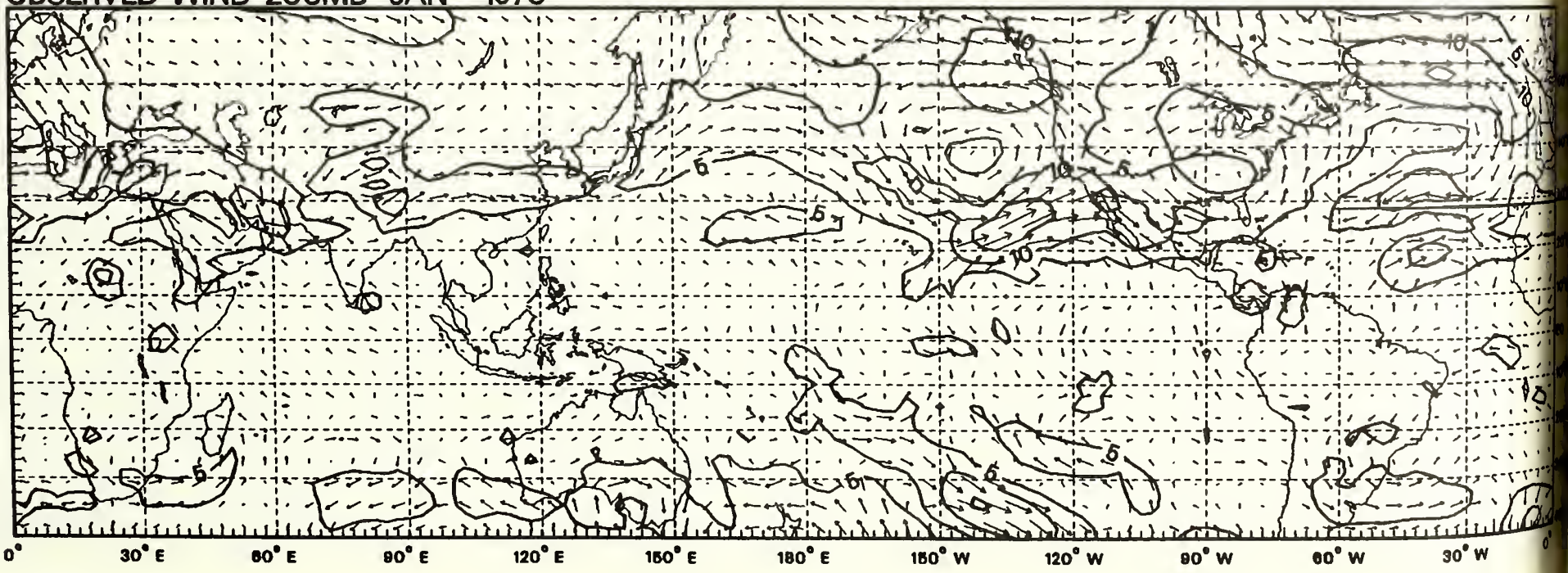

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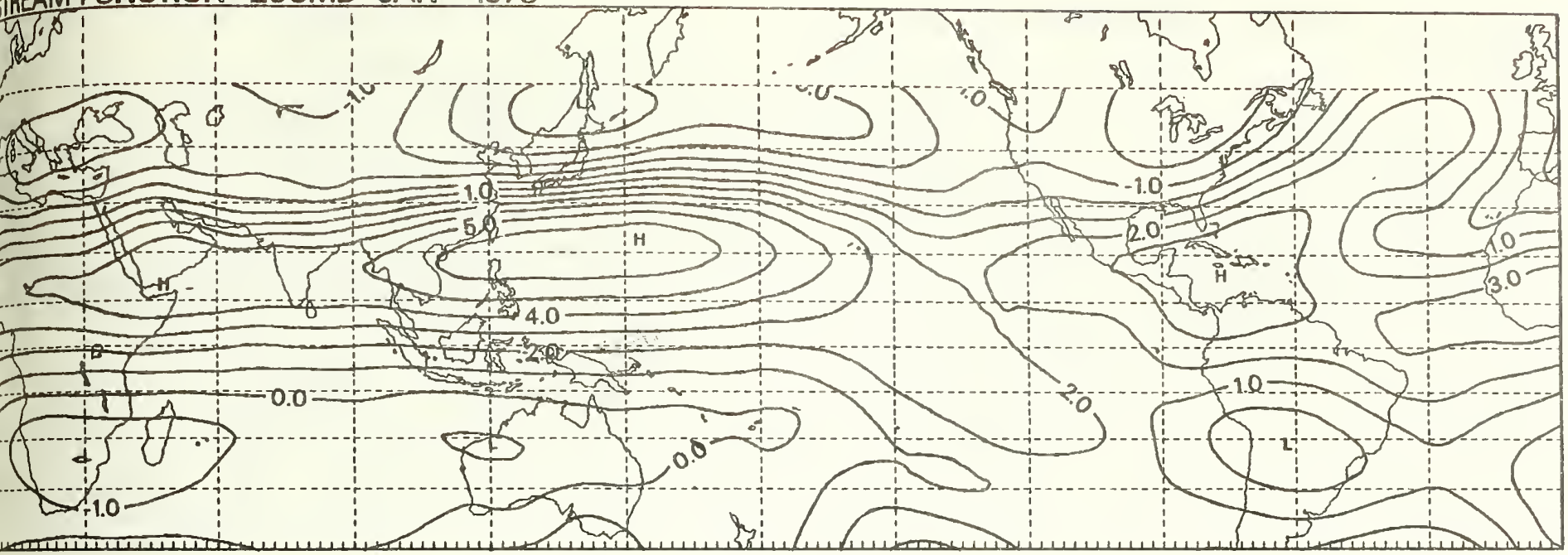

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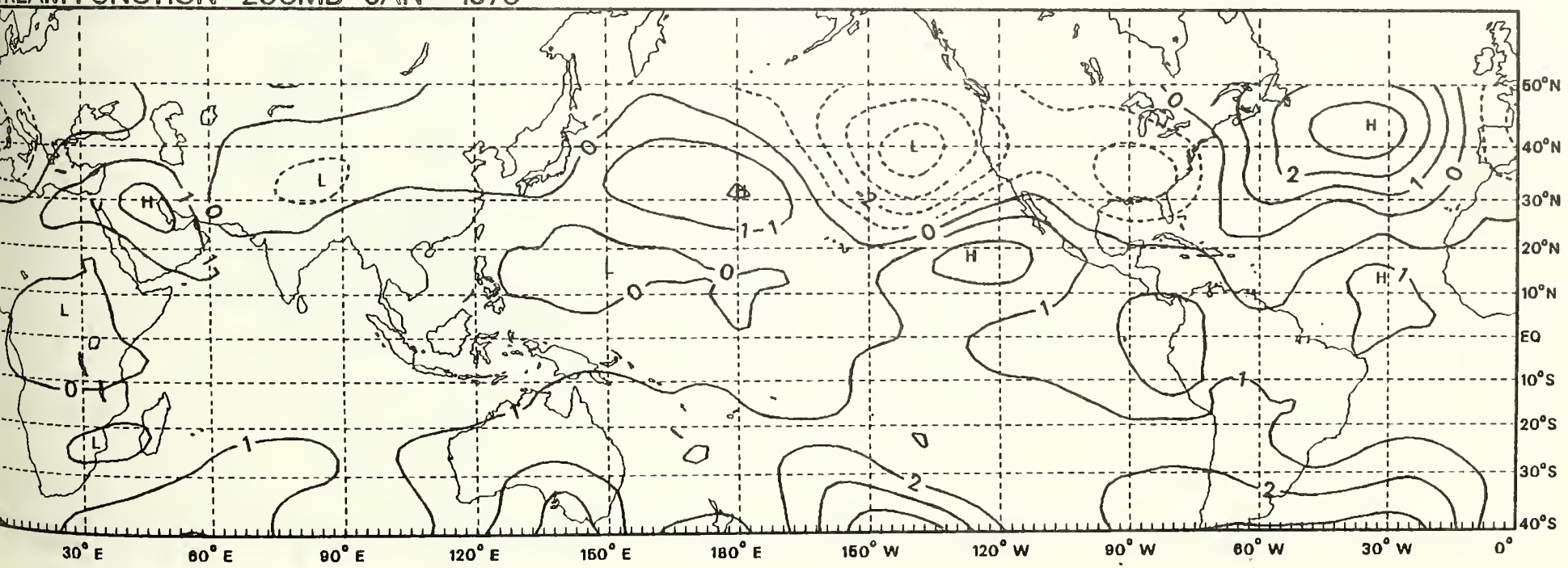

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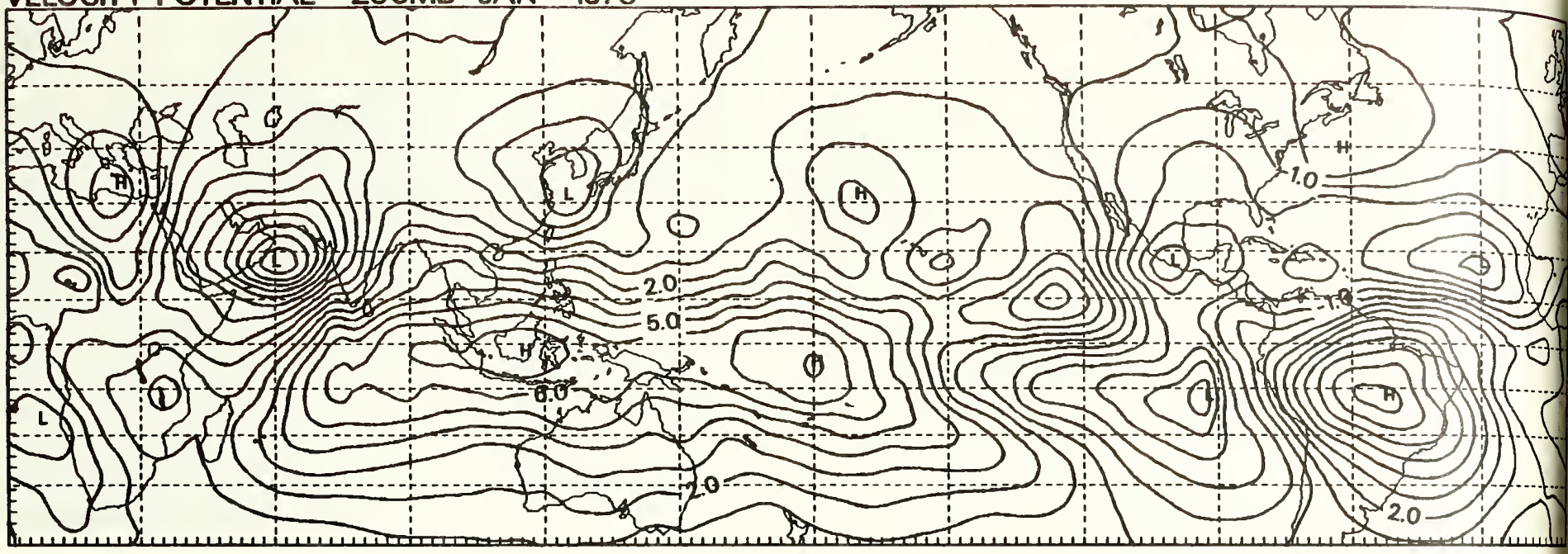

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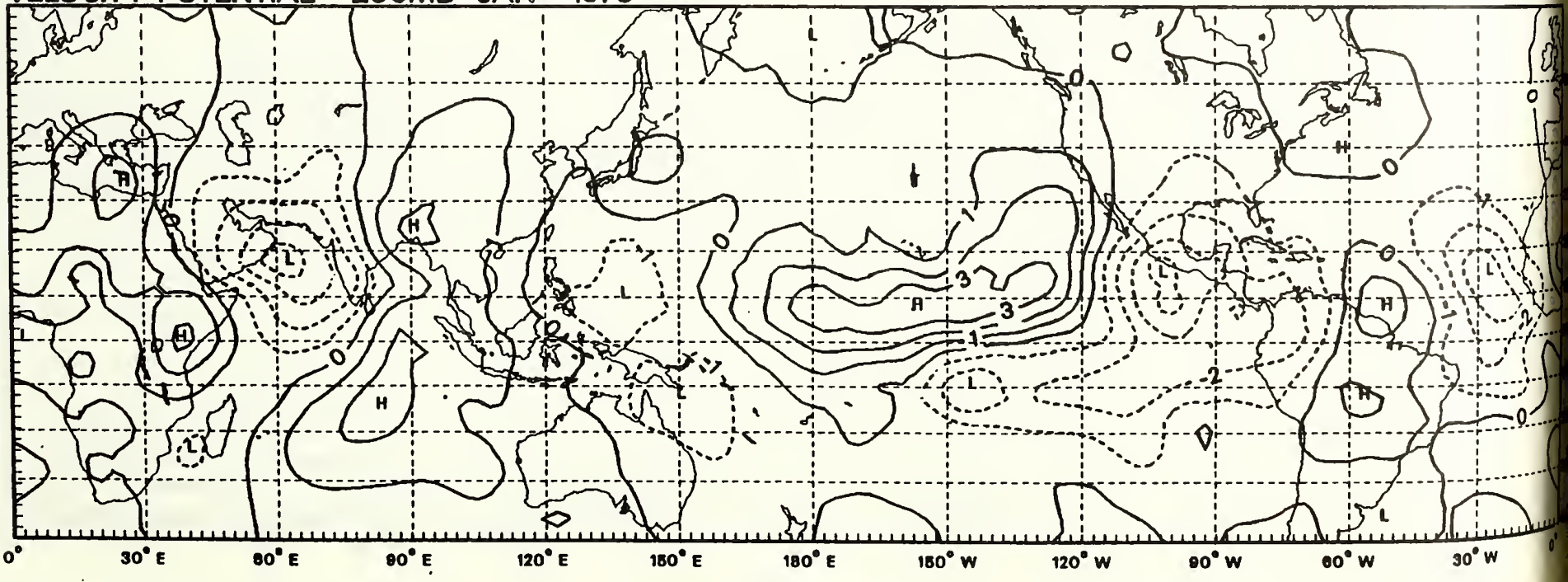

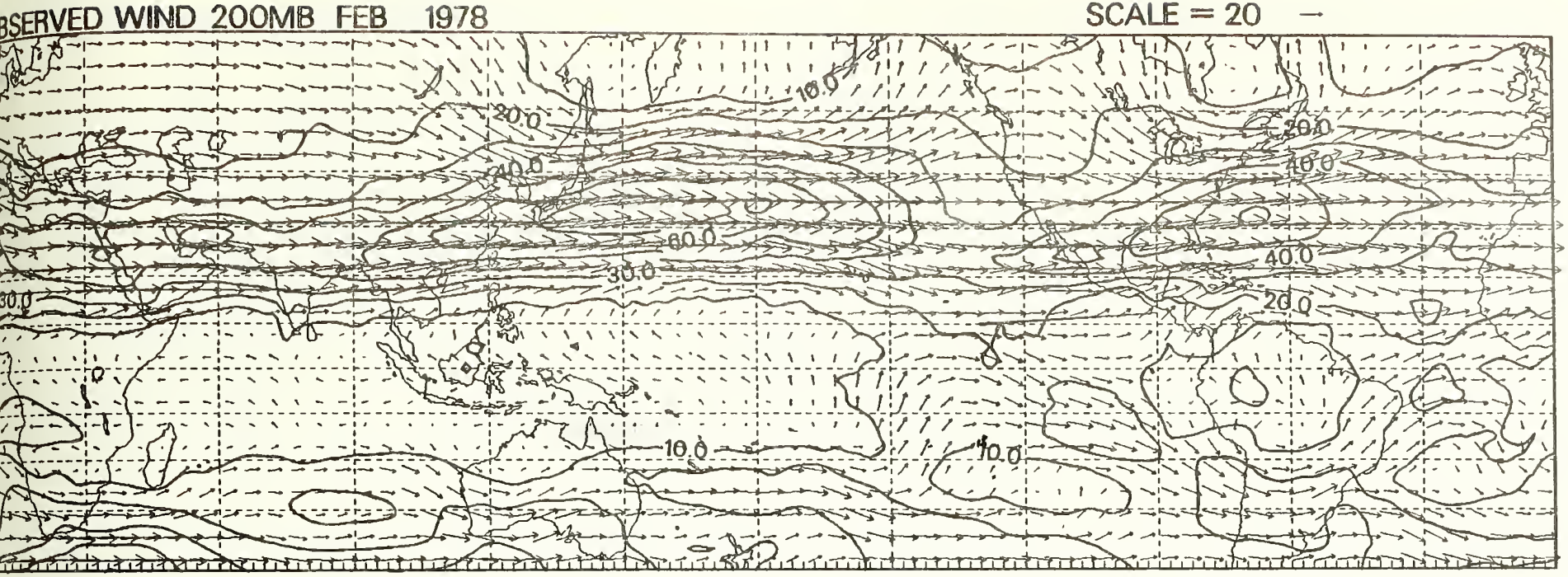
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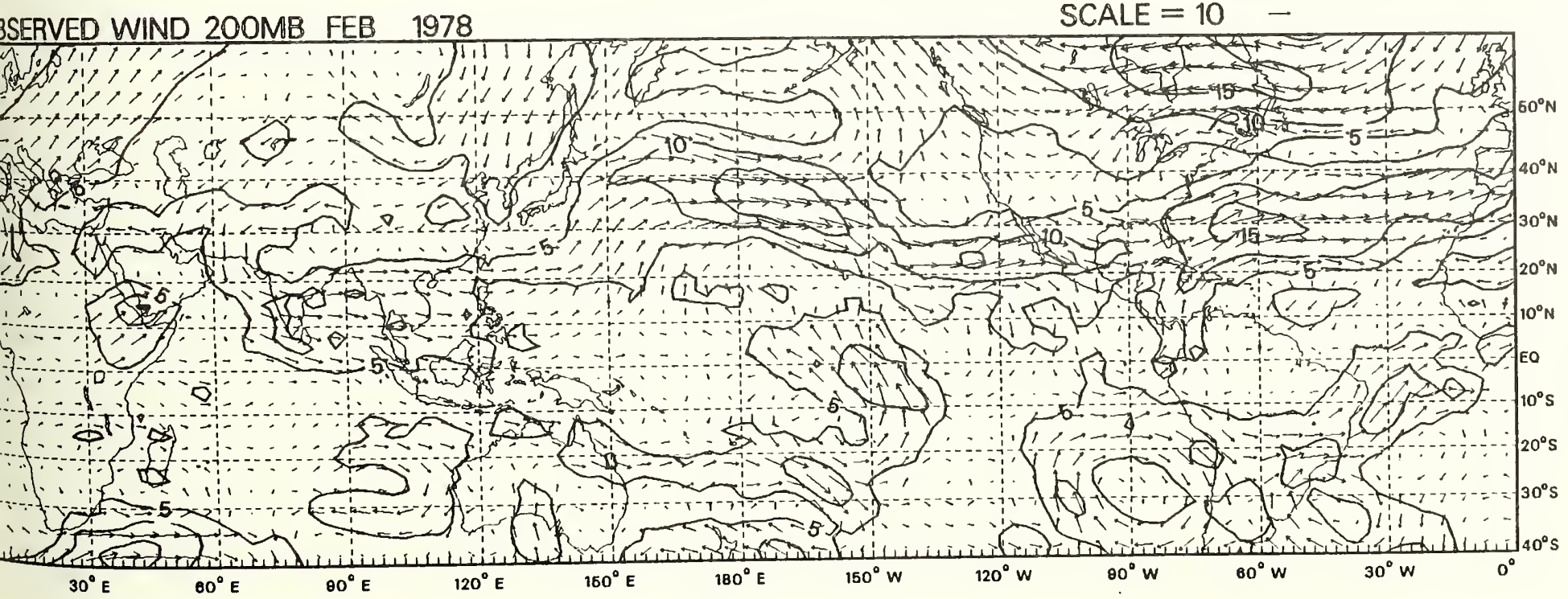
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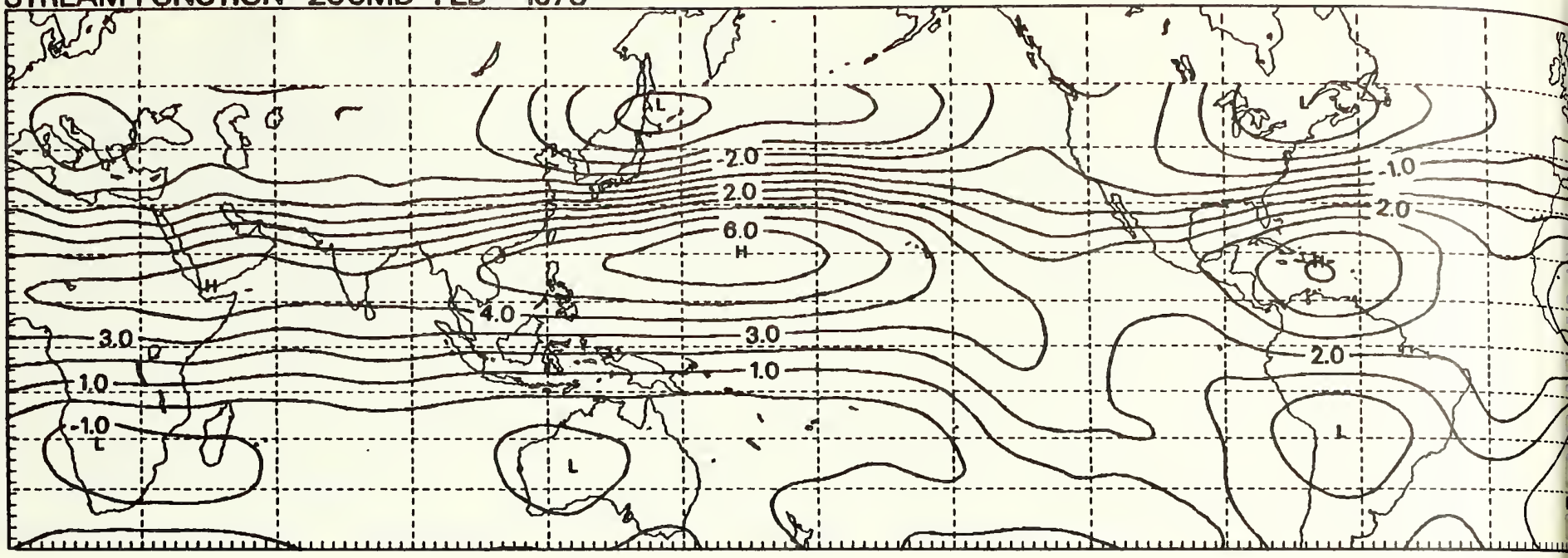

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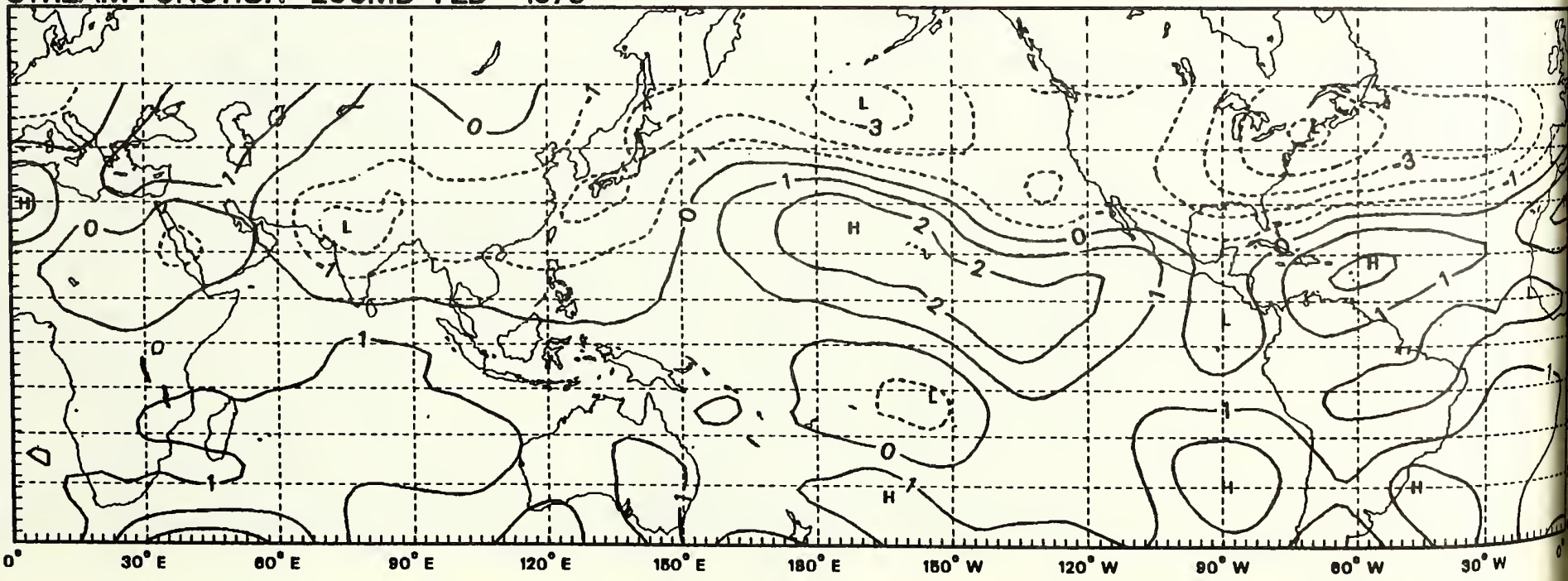

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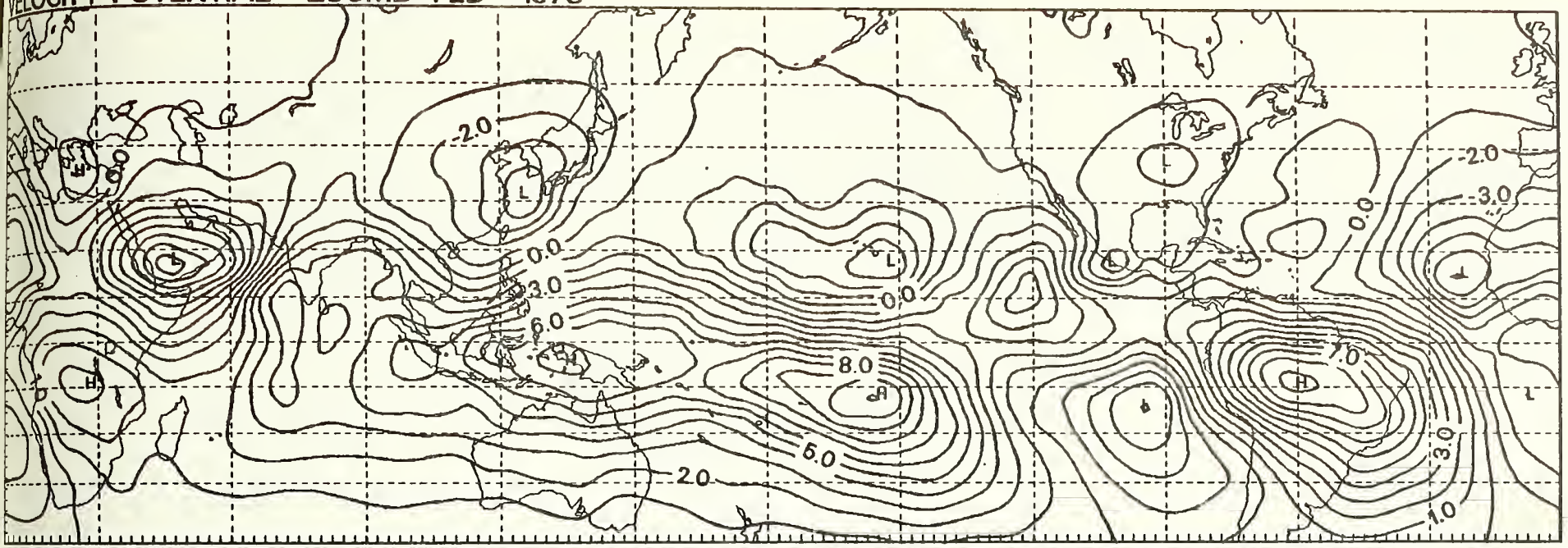

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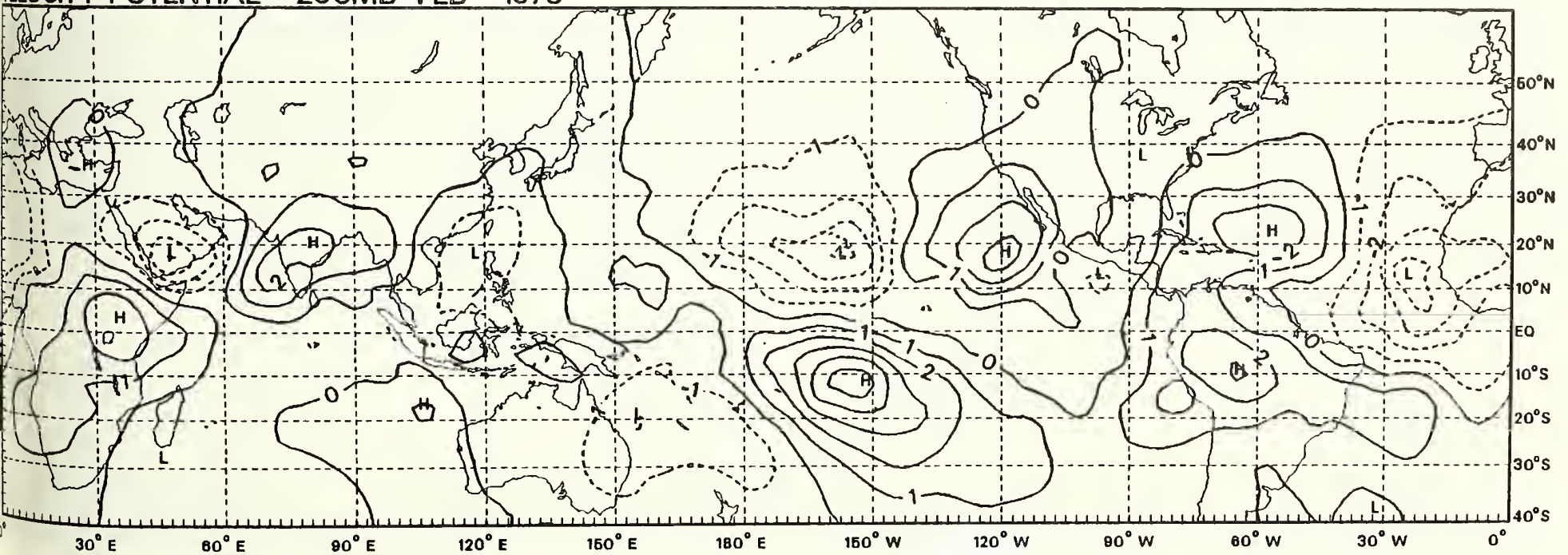

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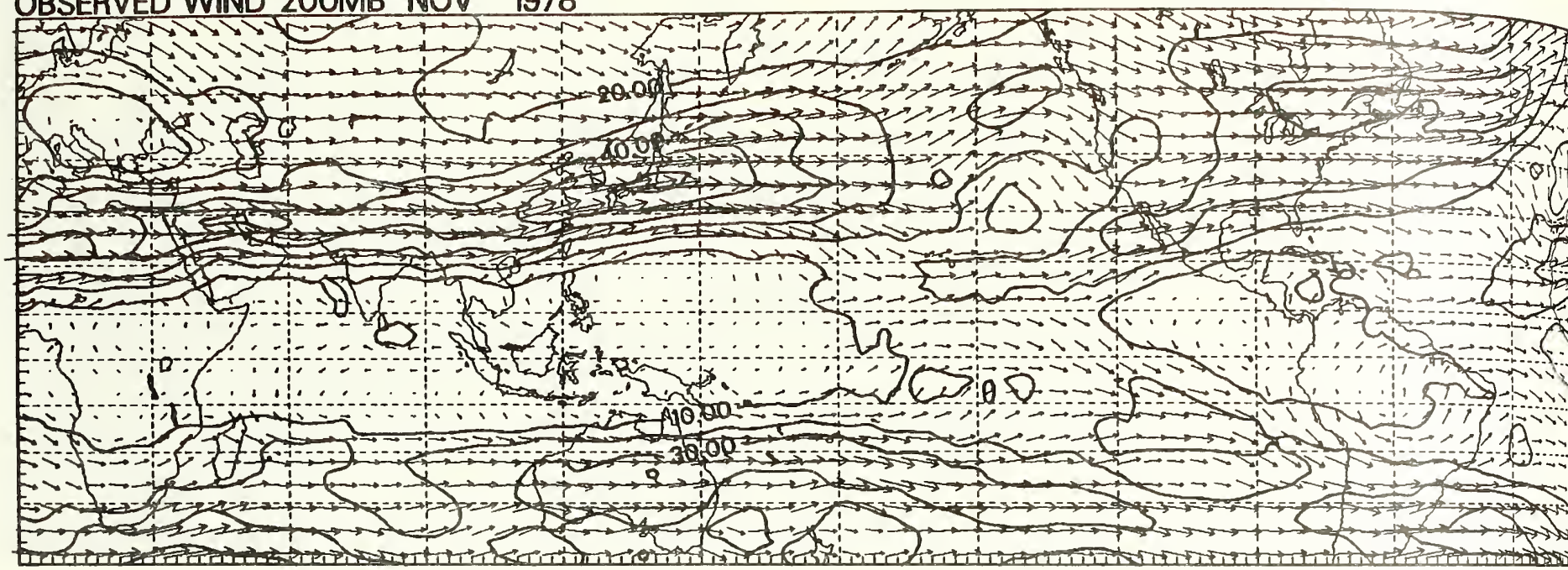

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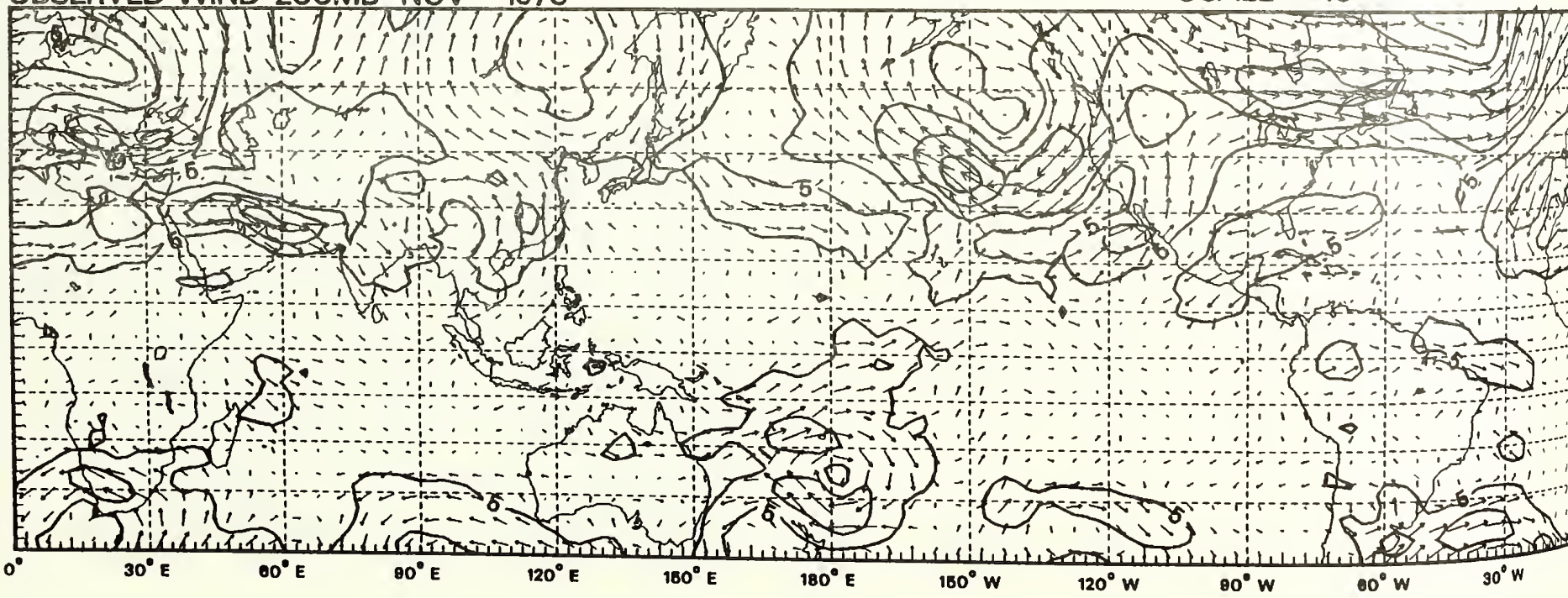

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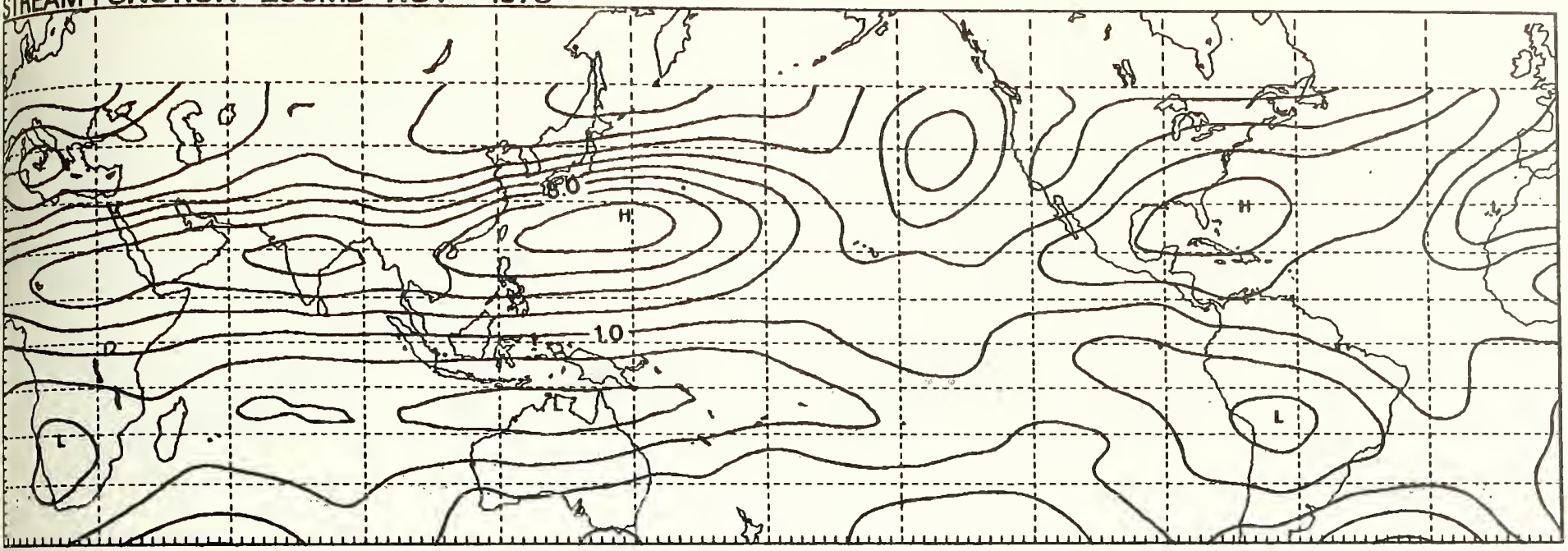

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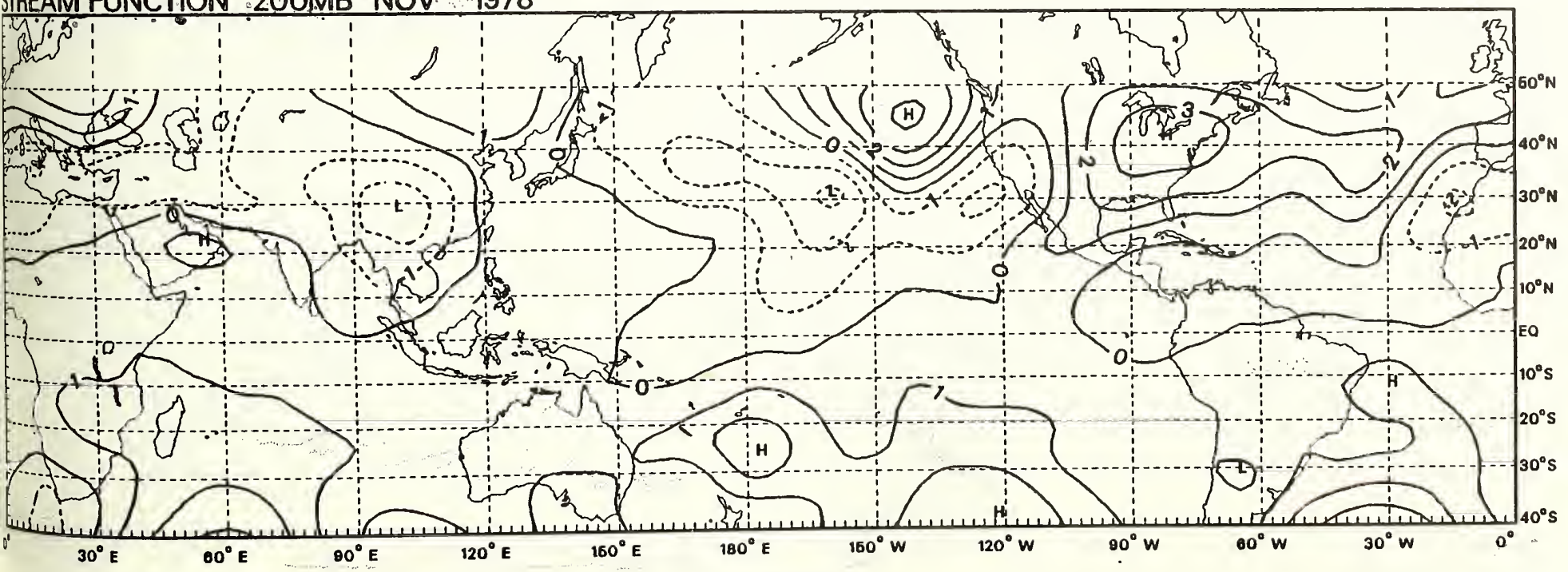

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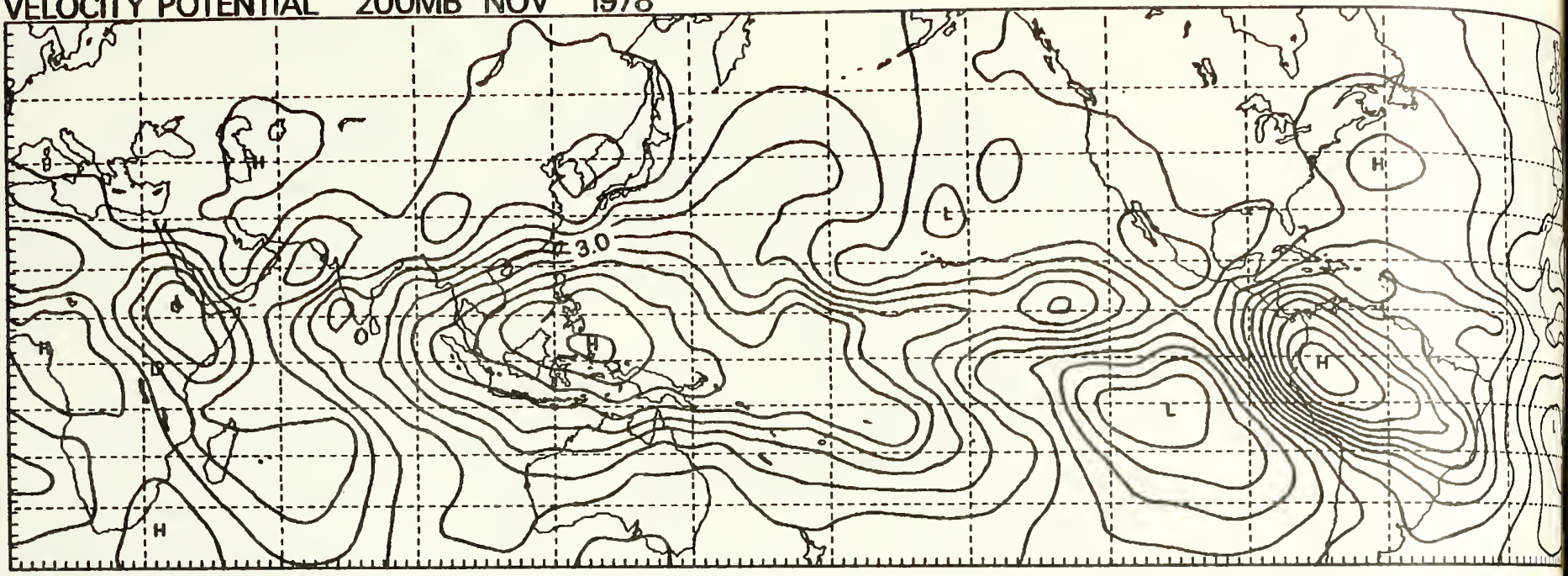

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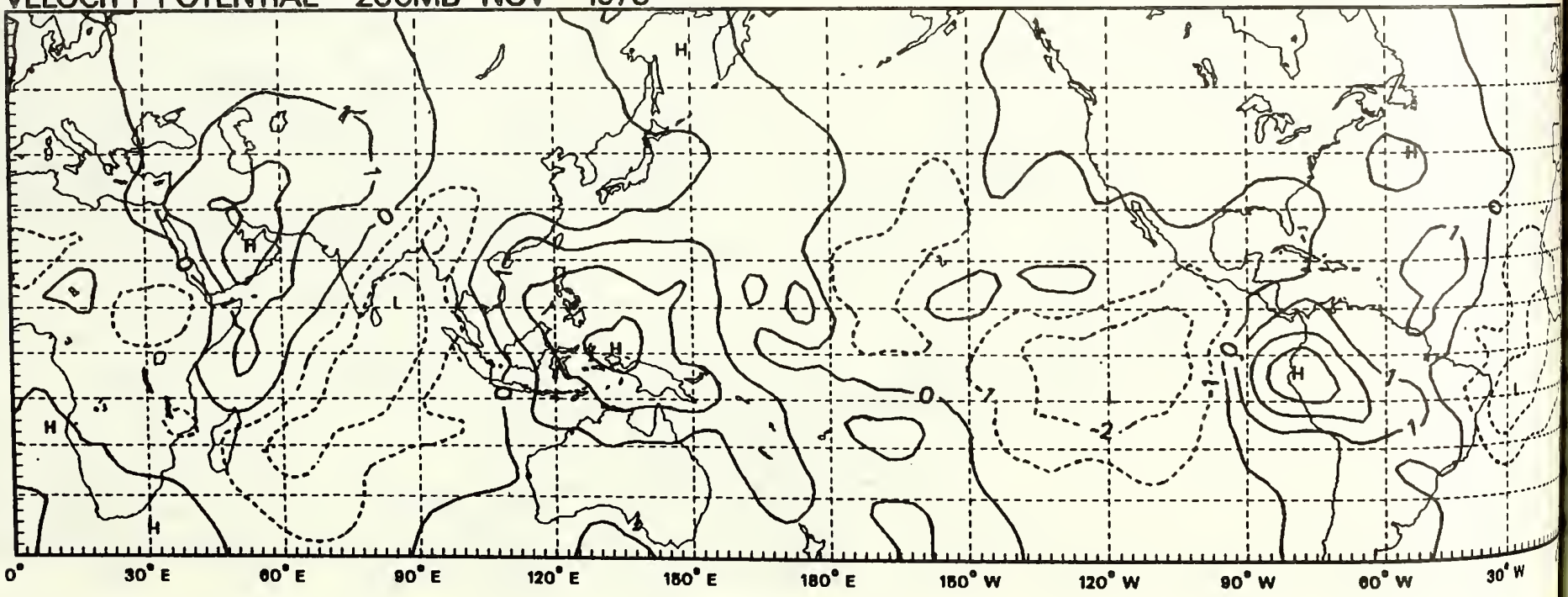

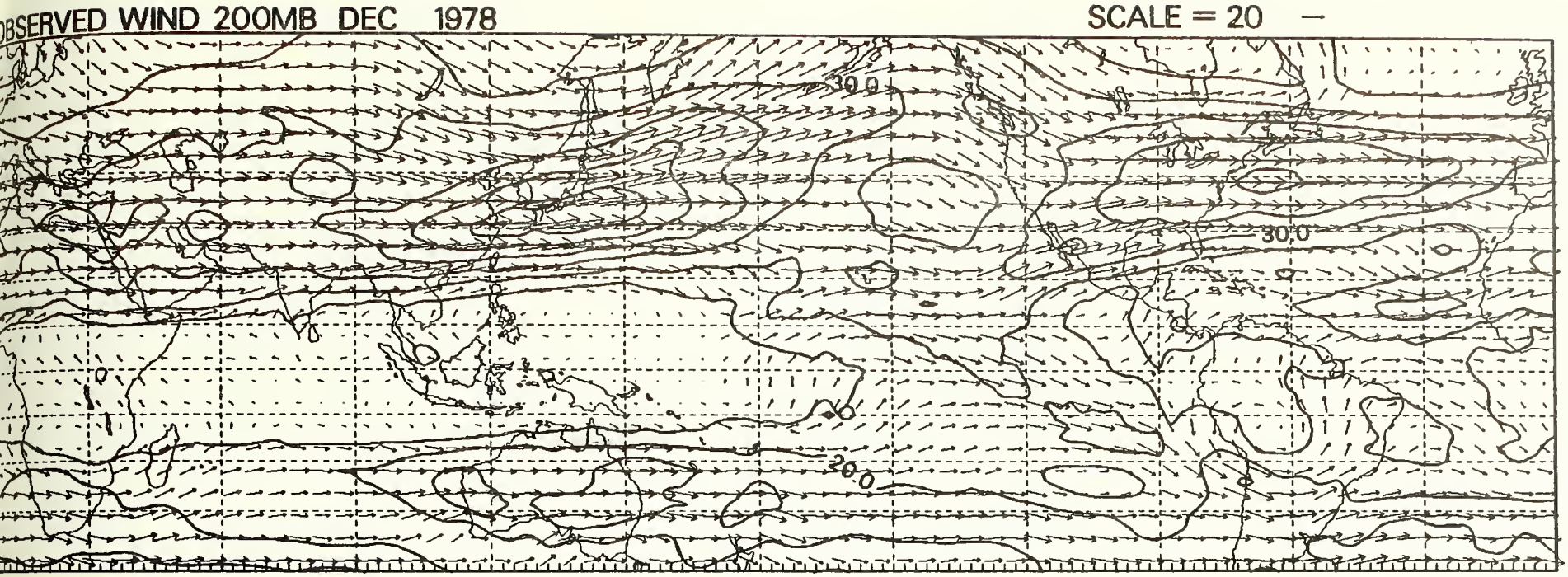
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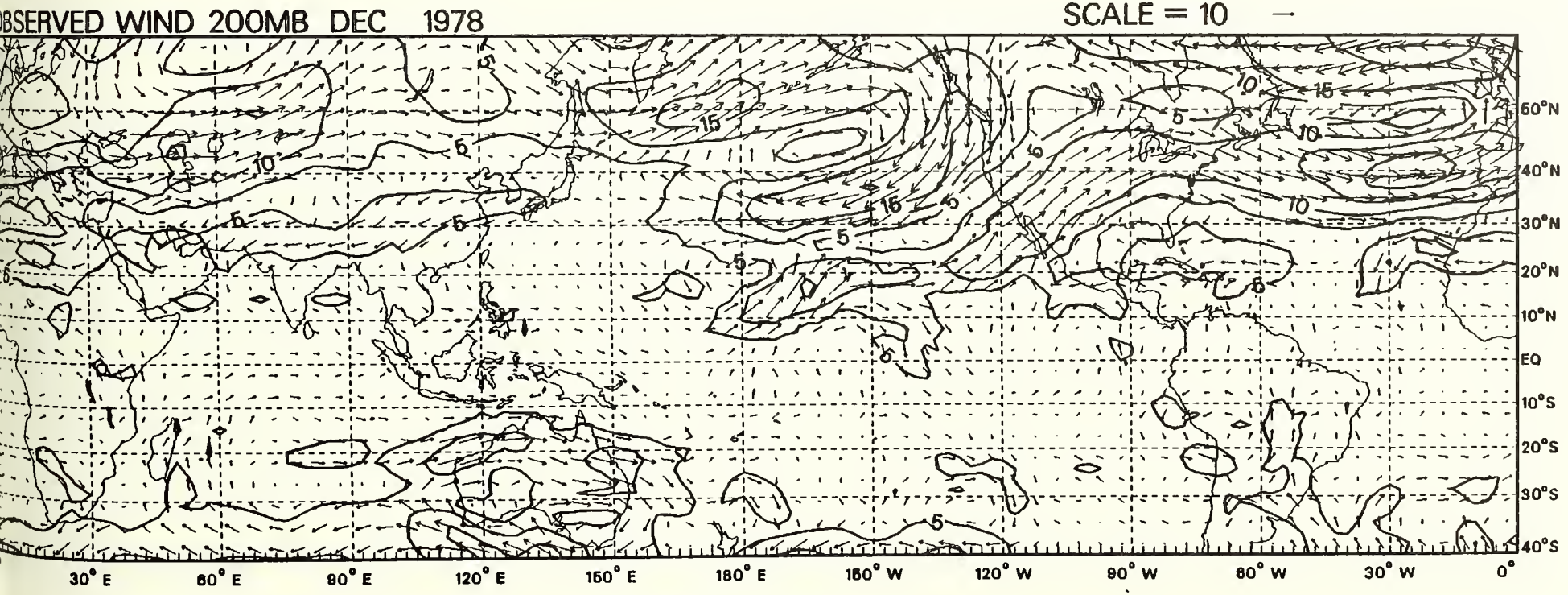
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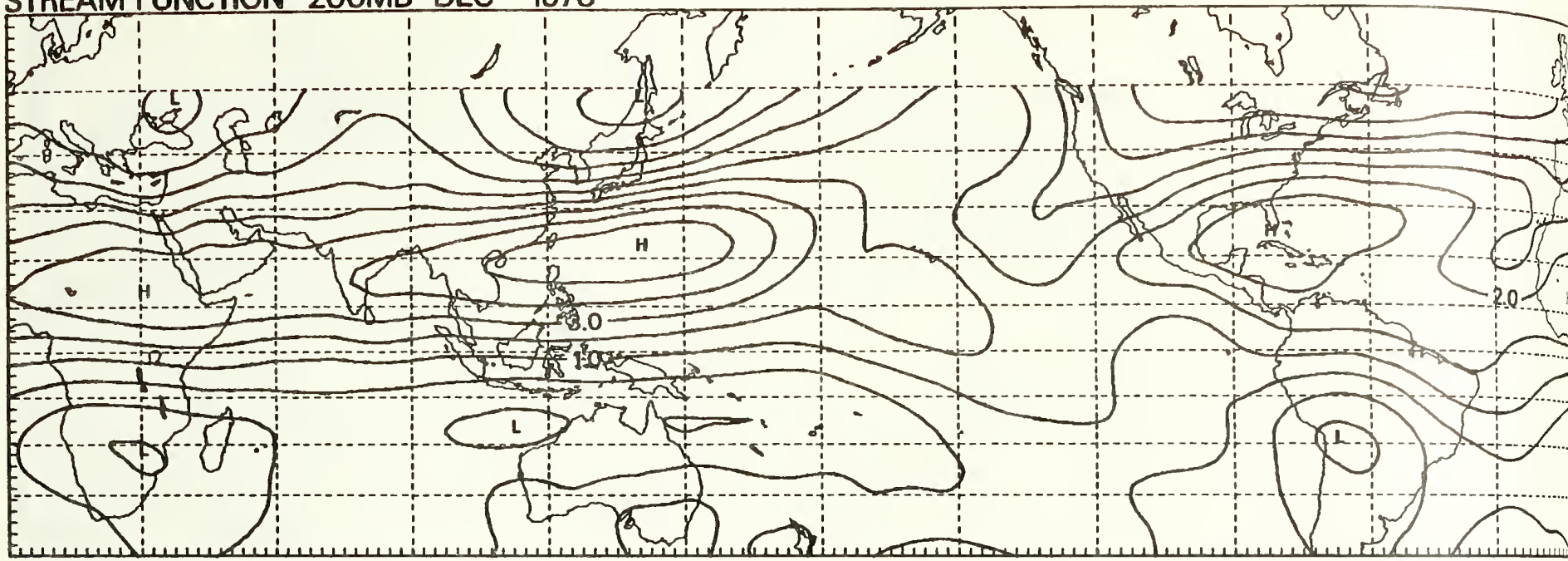
STREAM FUNCTION 200MB DEC 1978



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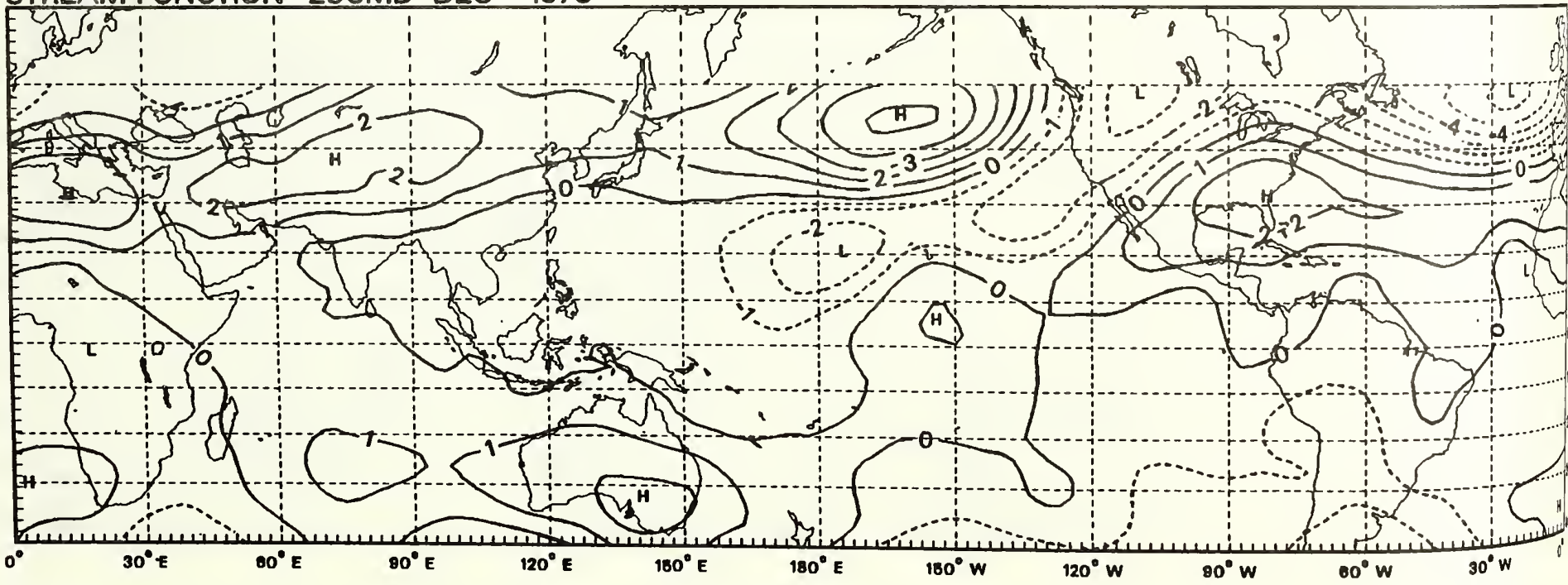

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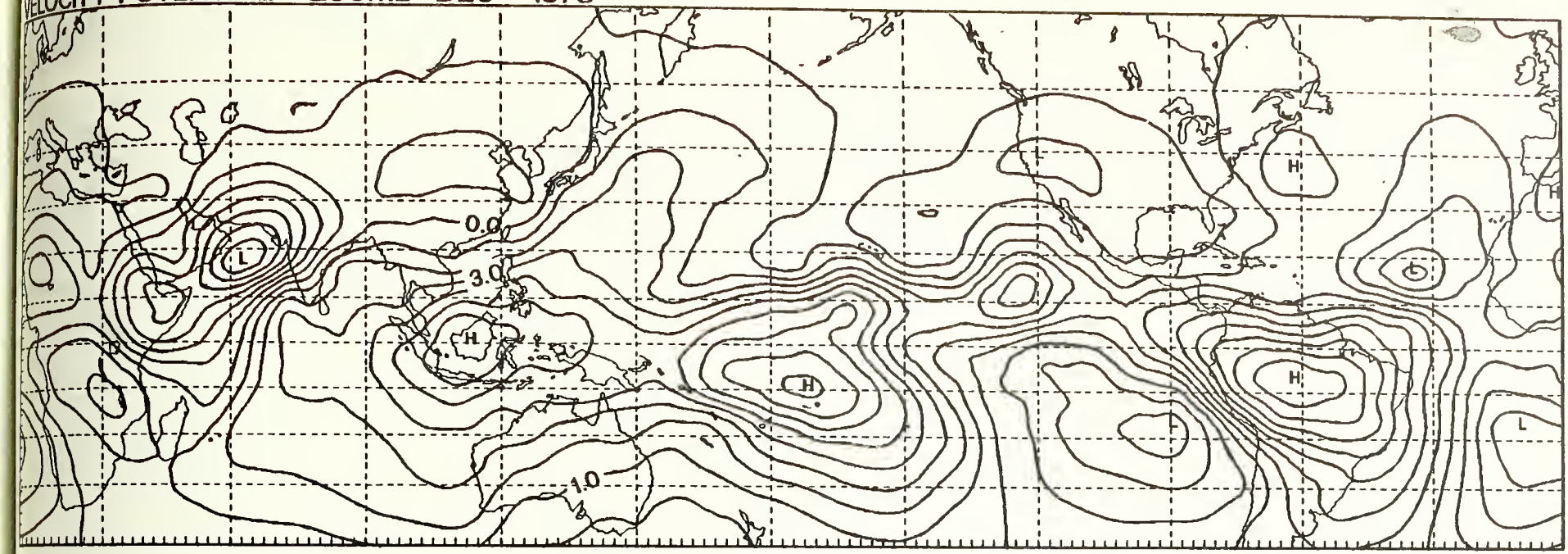

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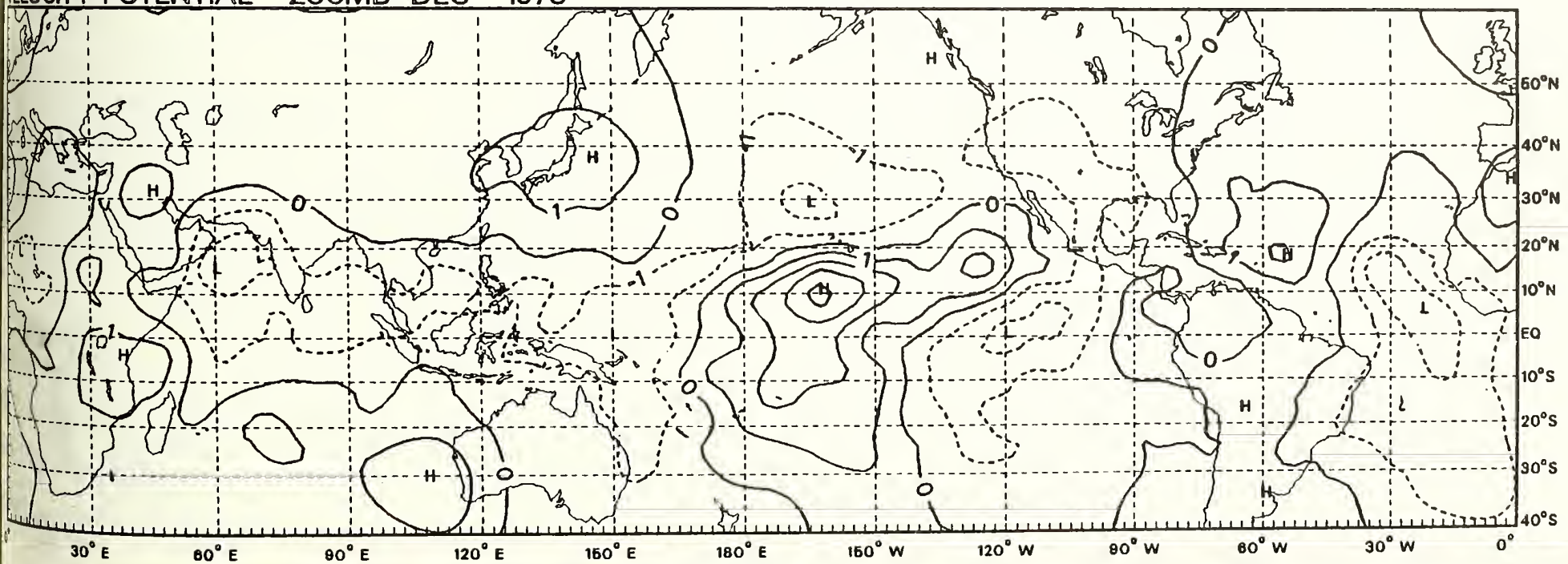

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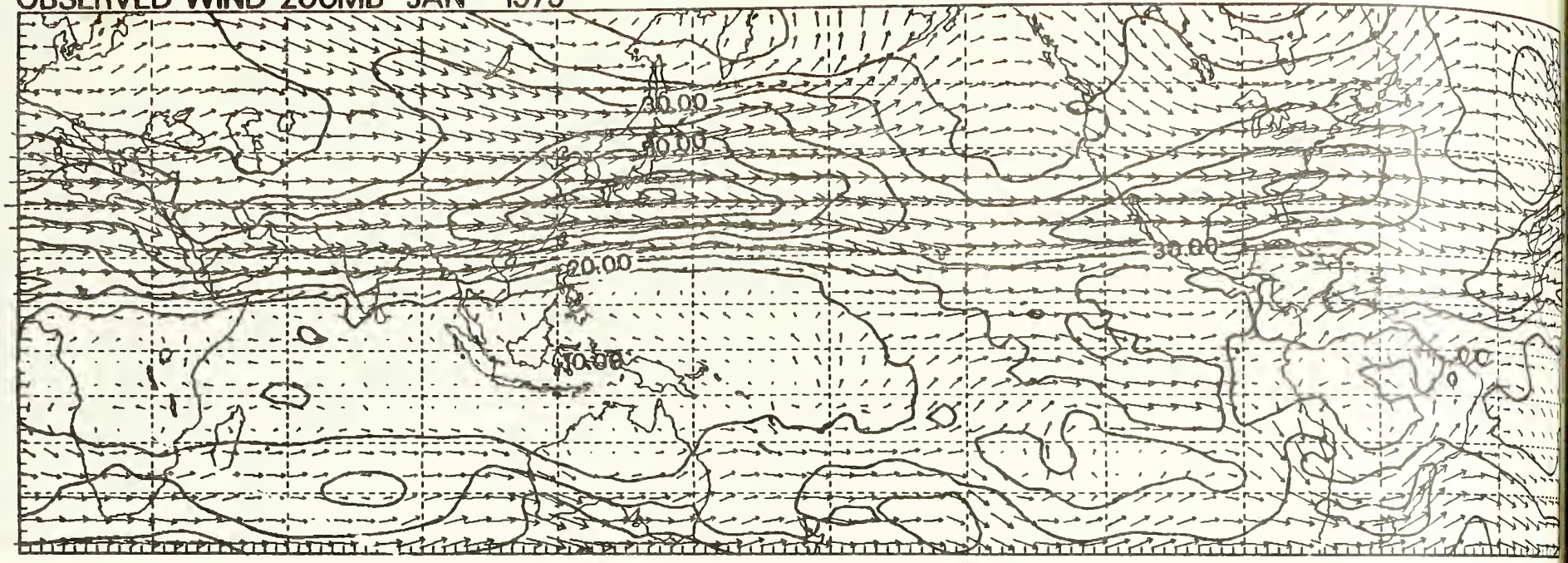

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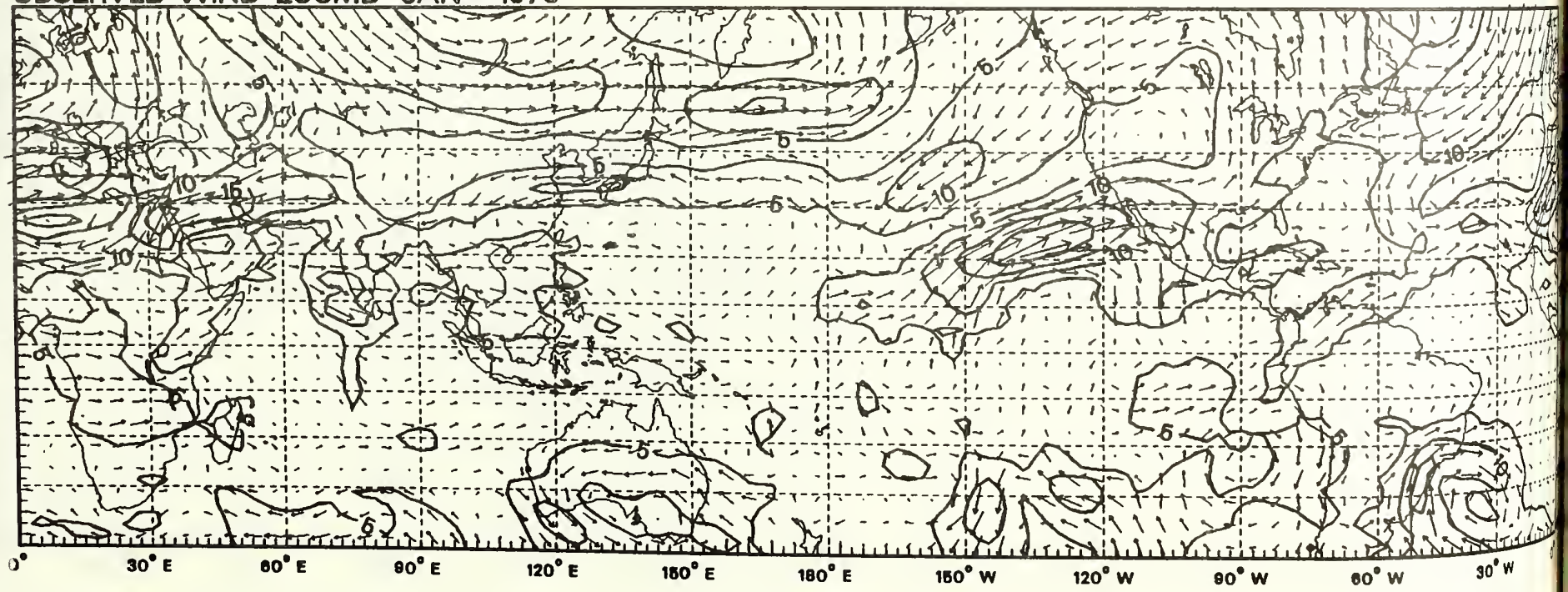

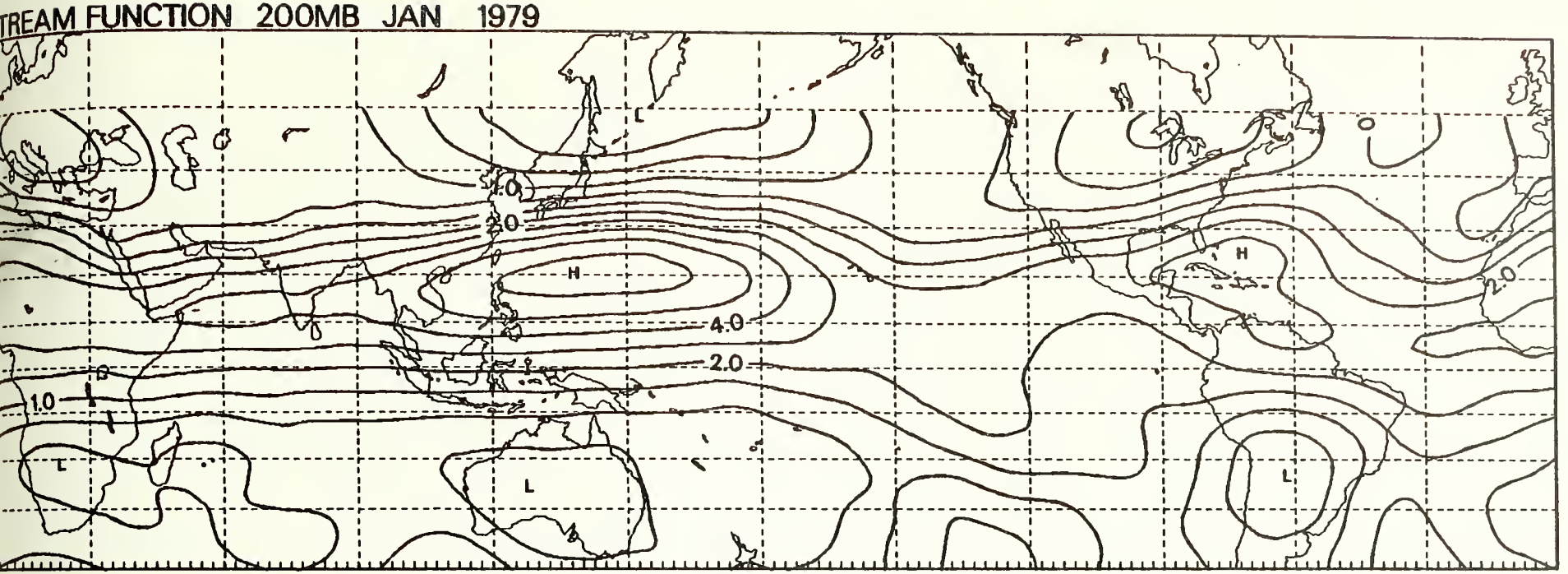
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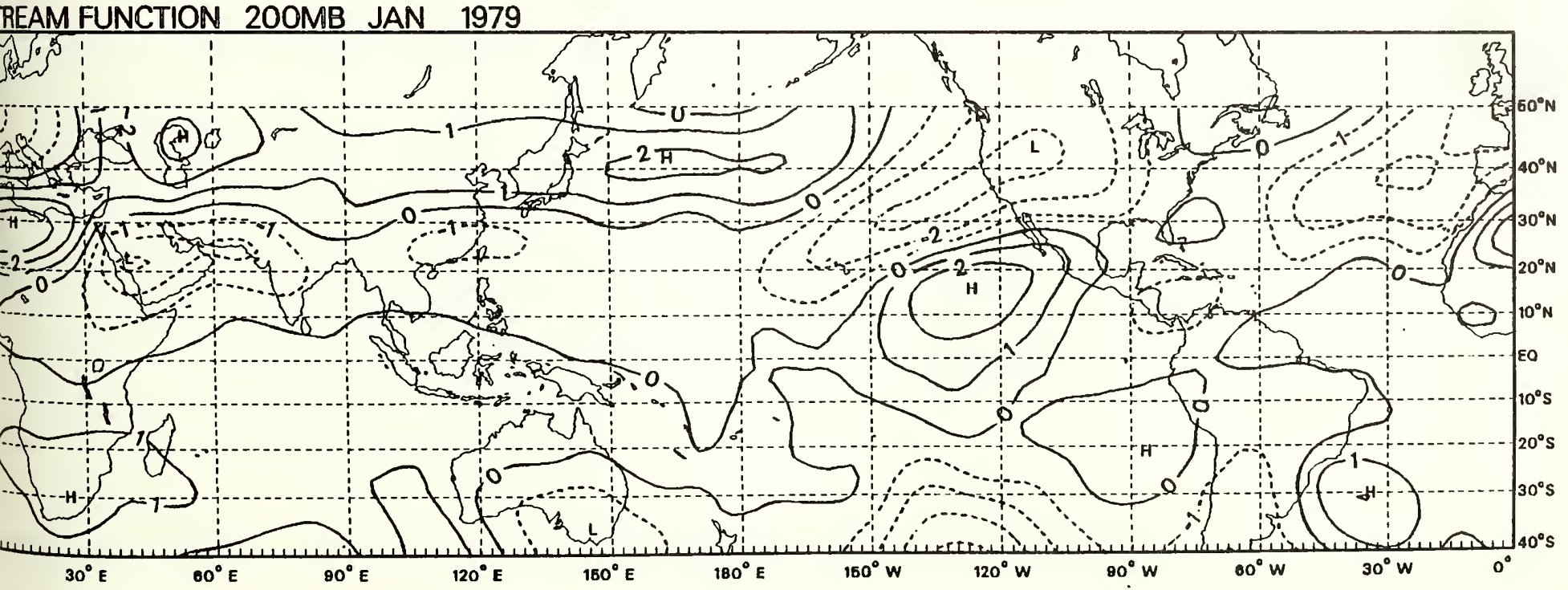
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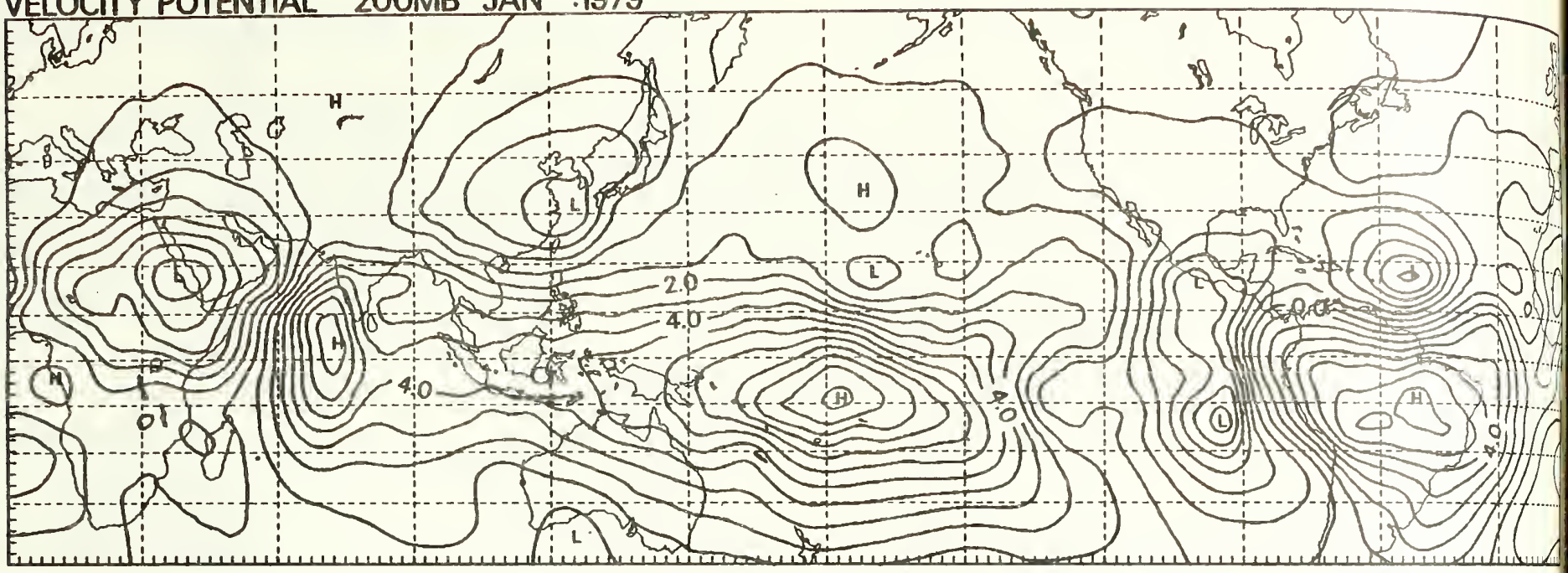
VELOCITY POTENTIAL 200MB JAN 1979



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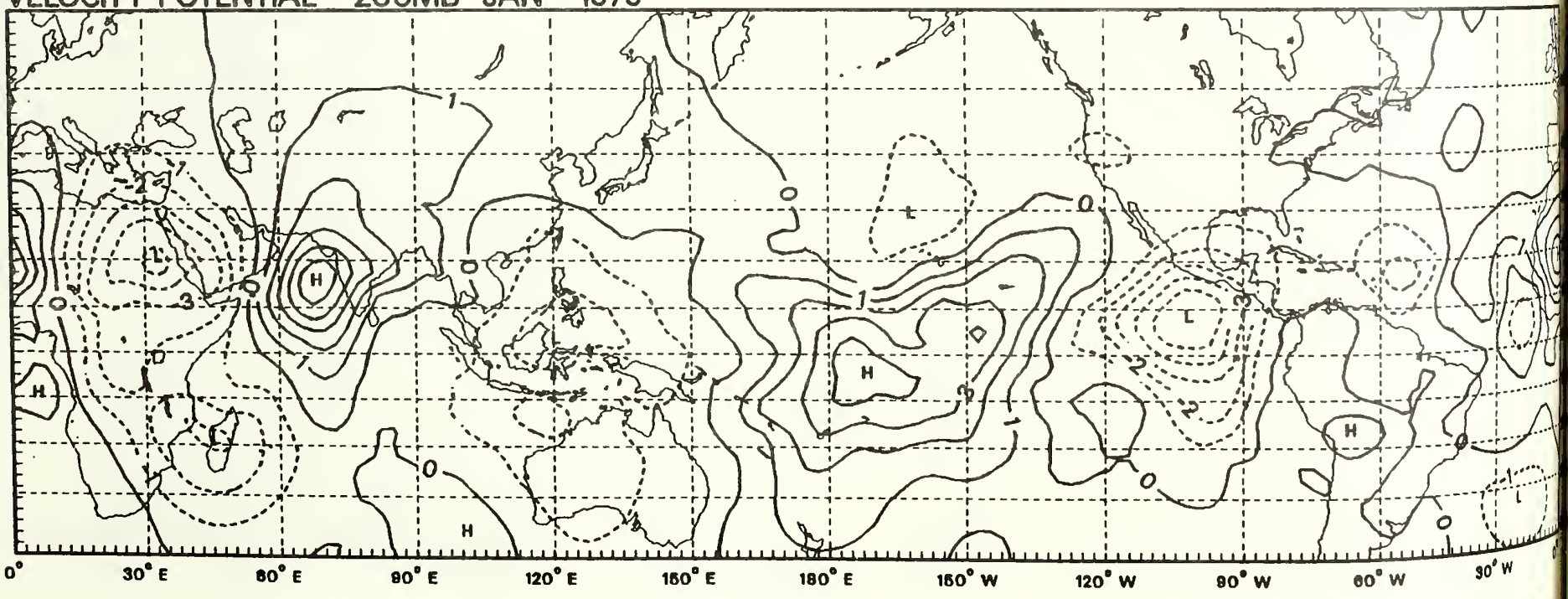

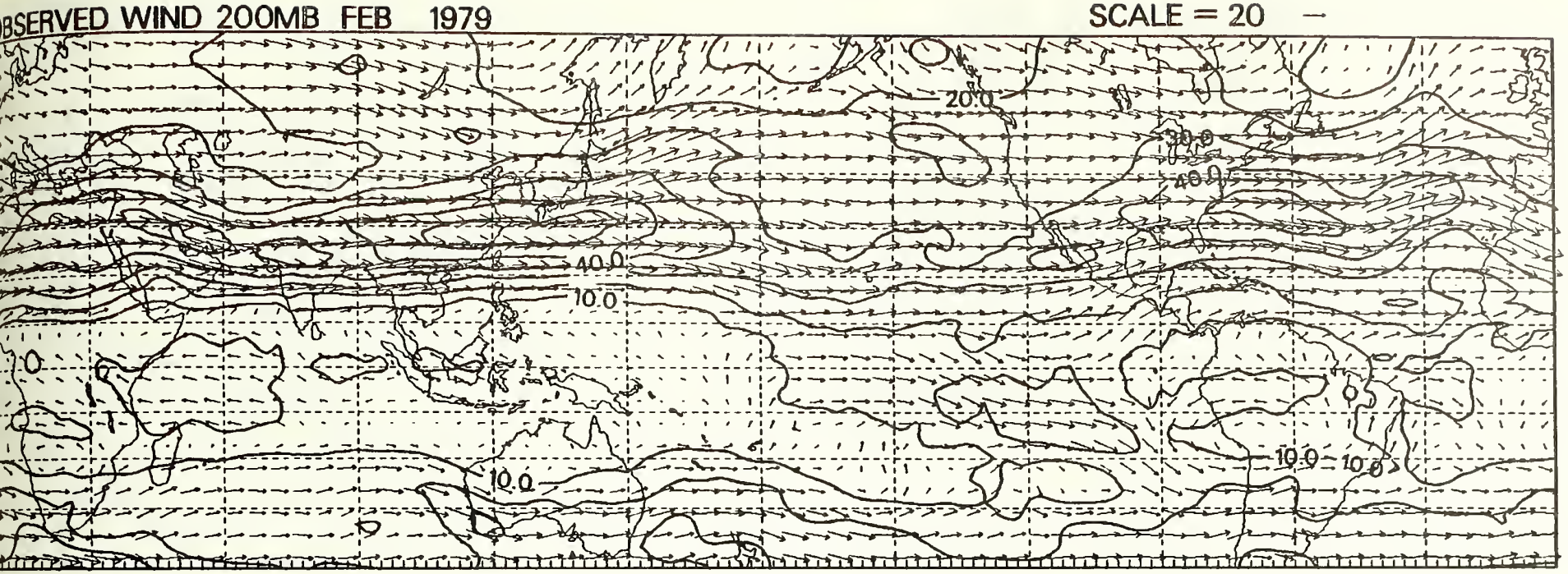
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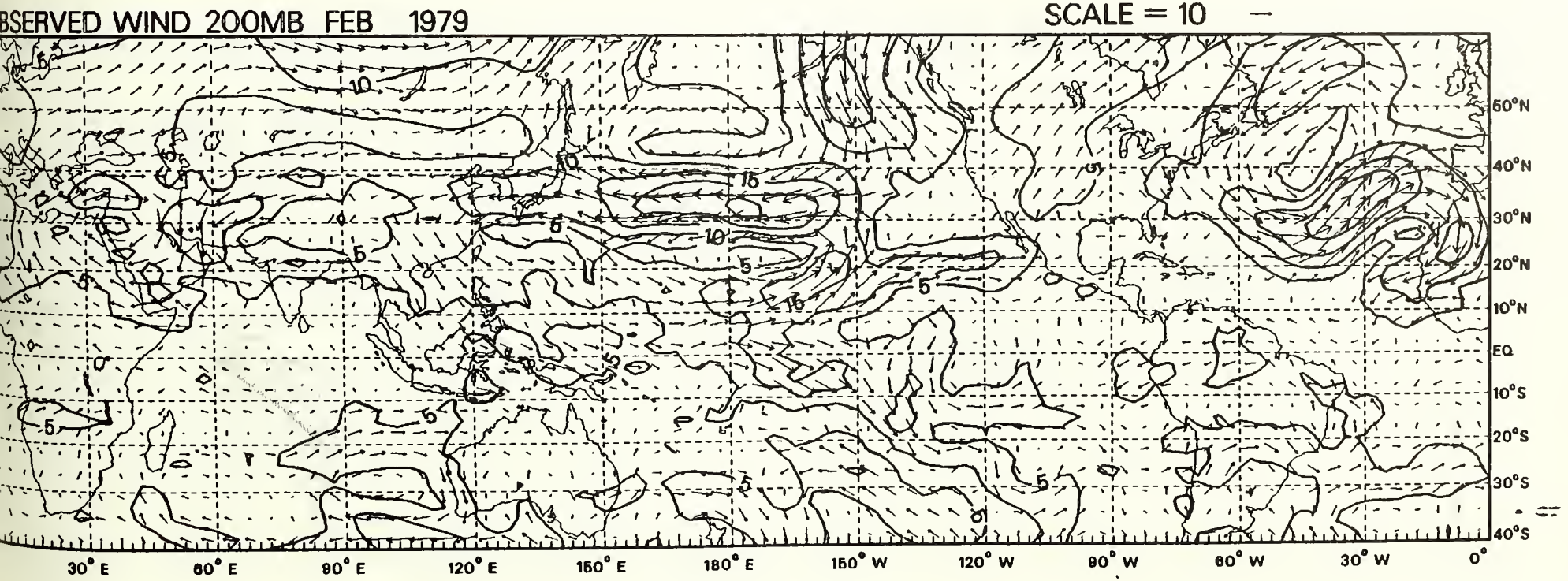
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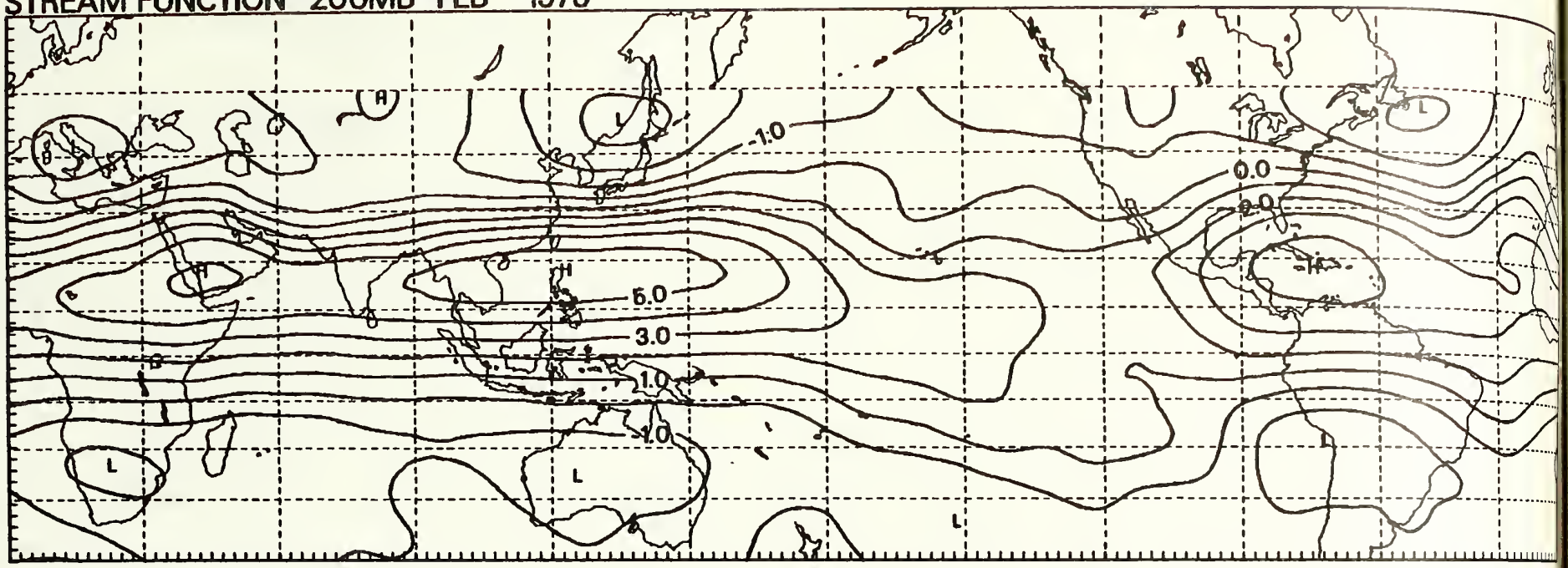

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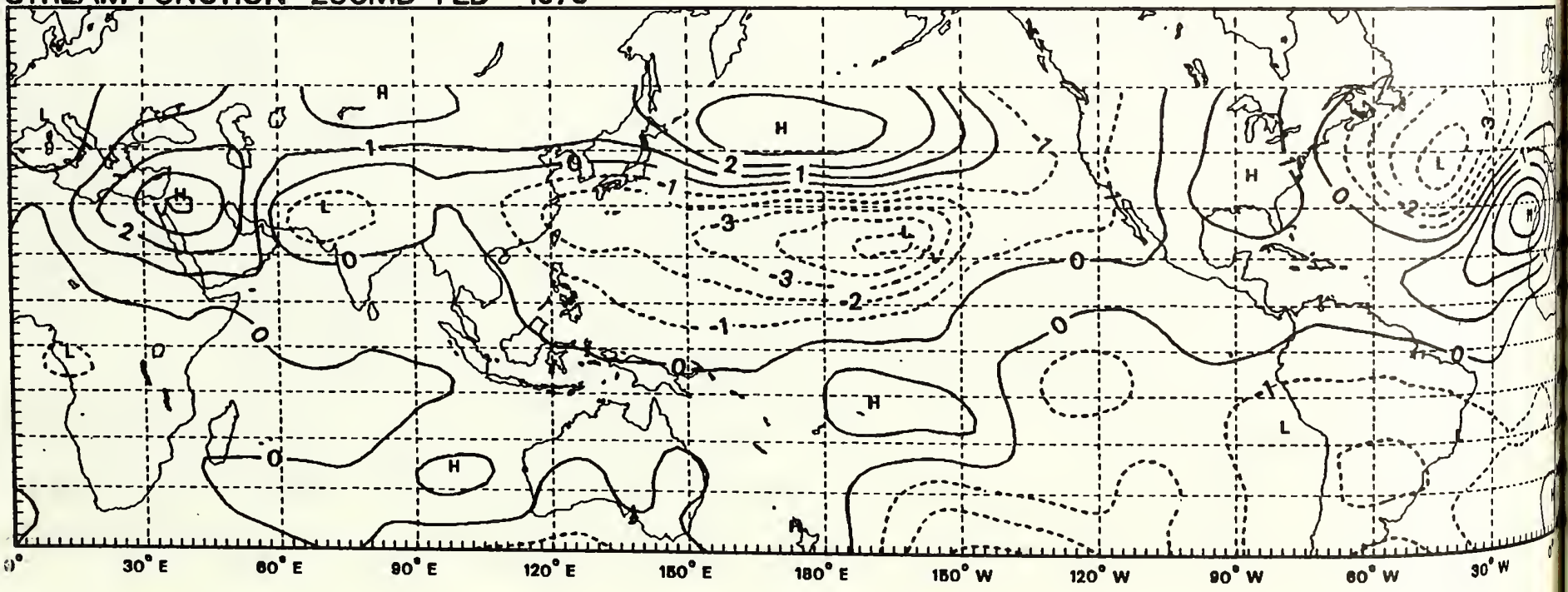

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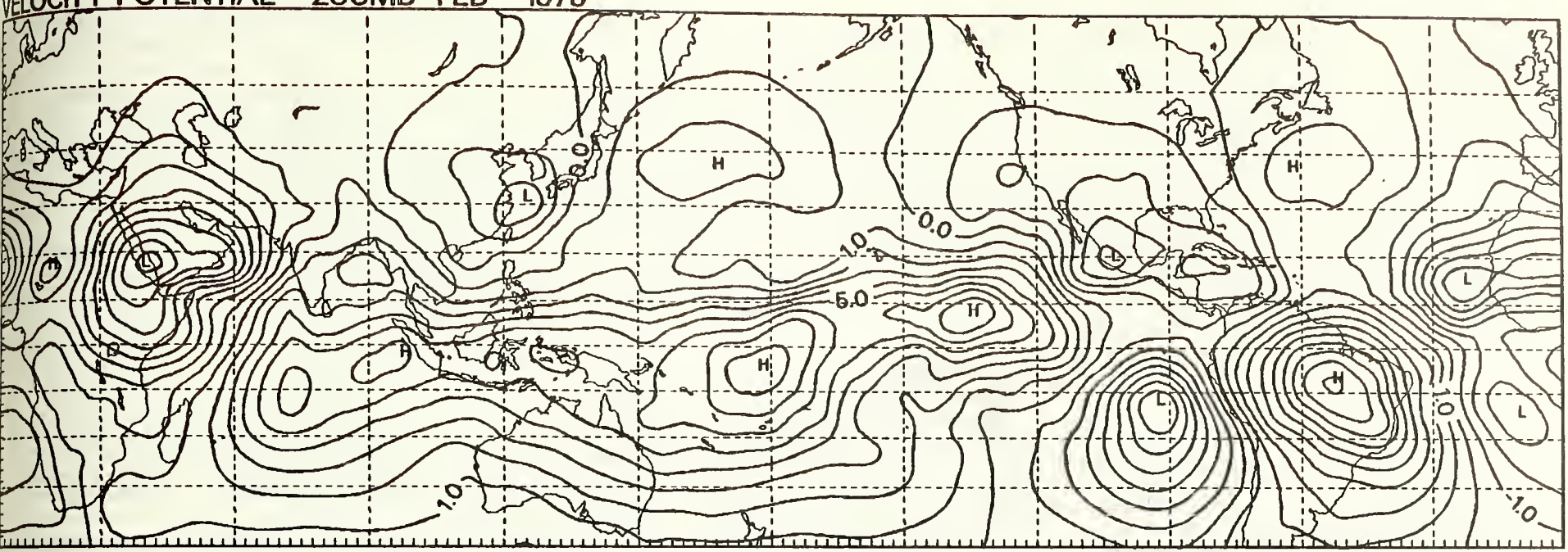

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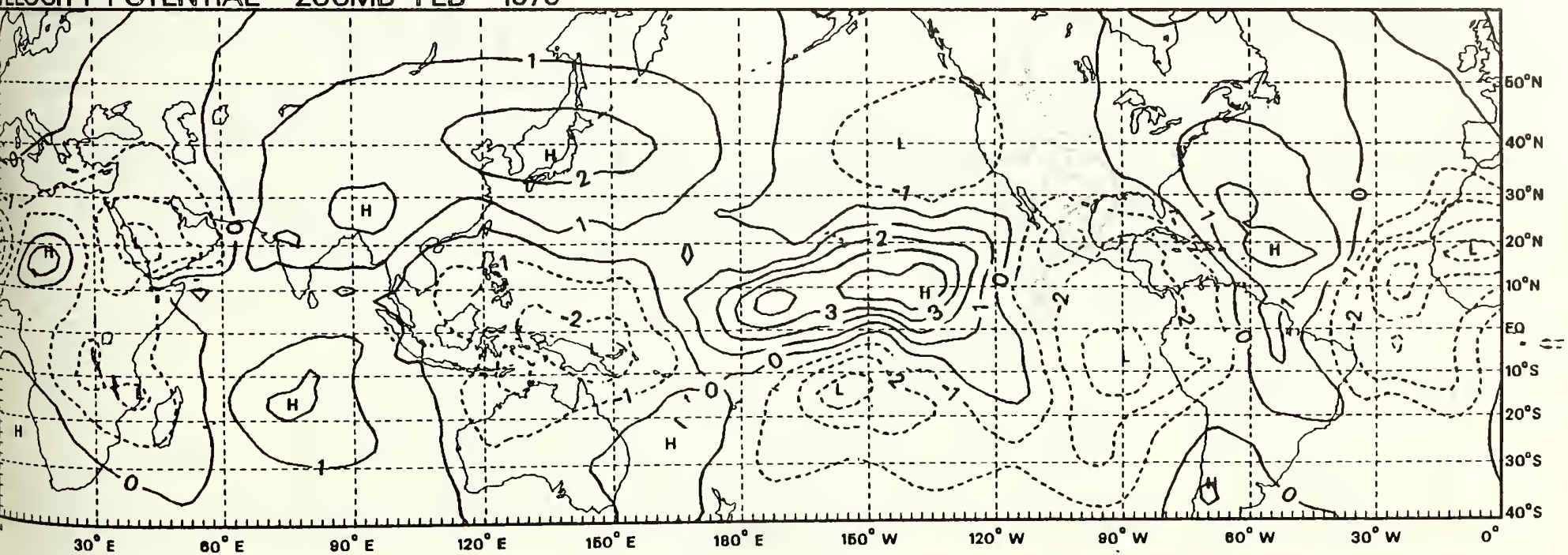

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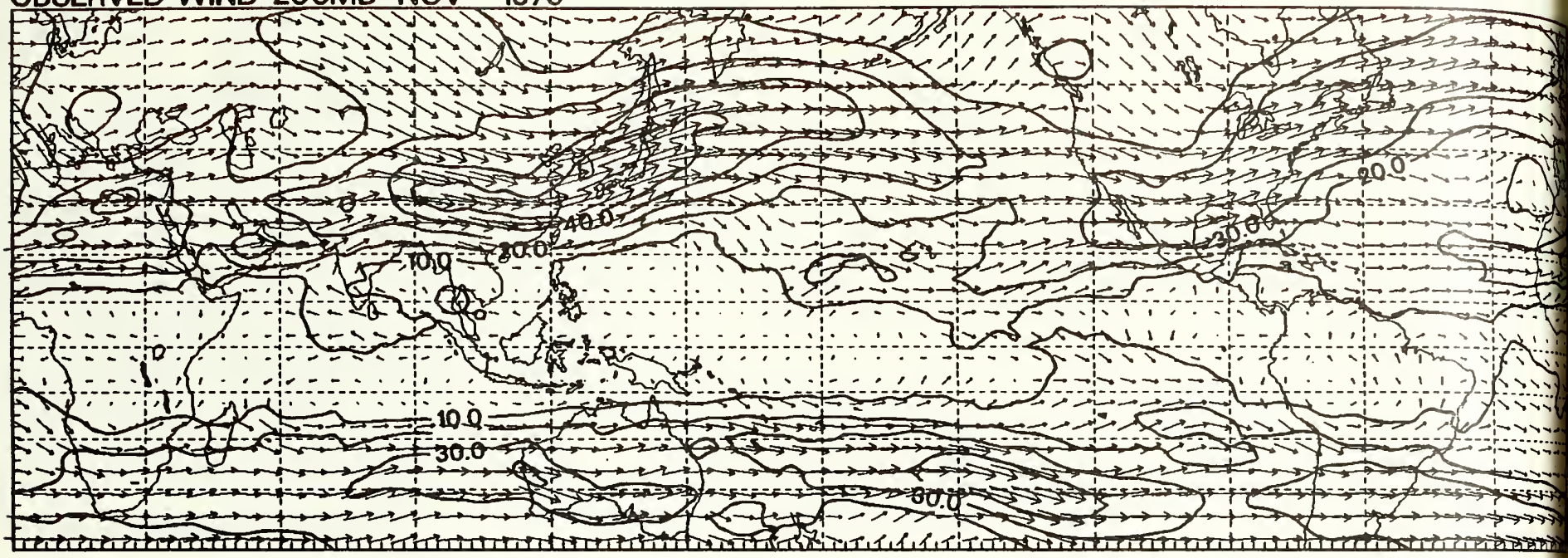

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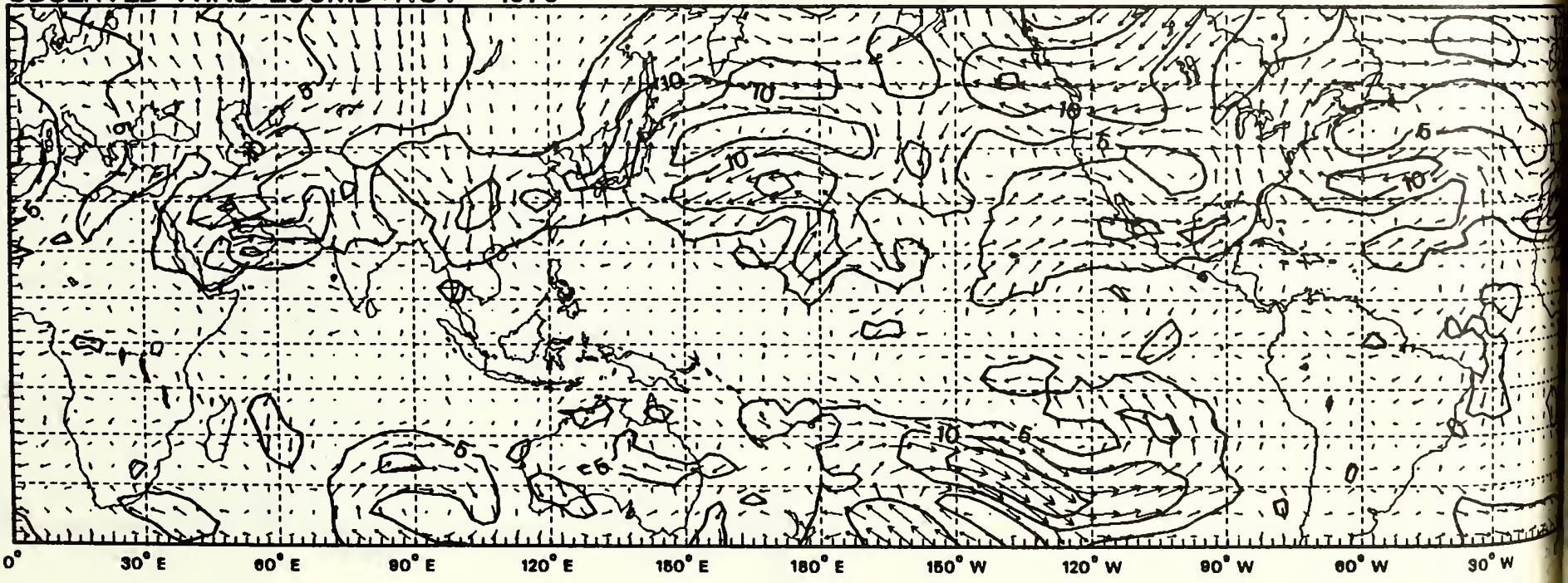
10
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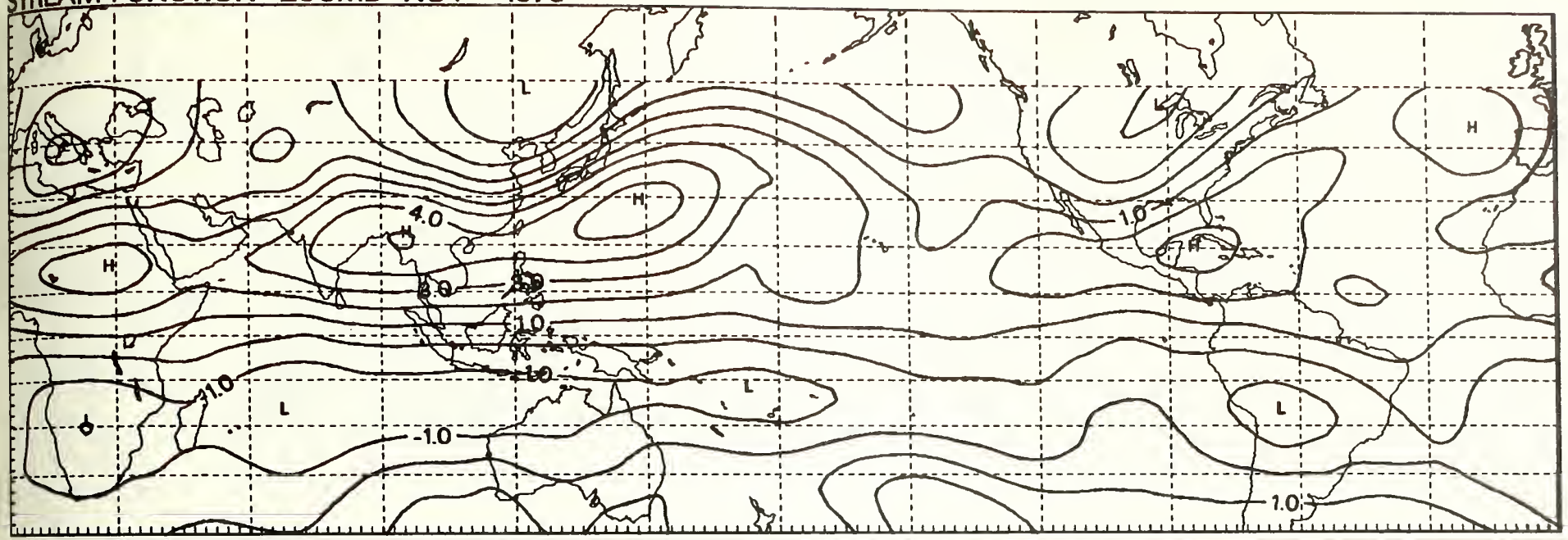
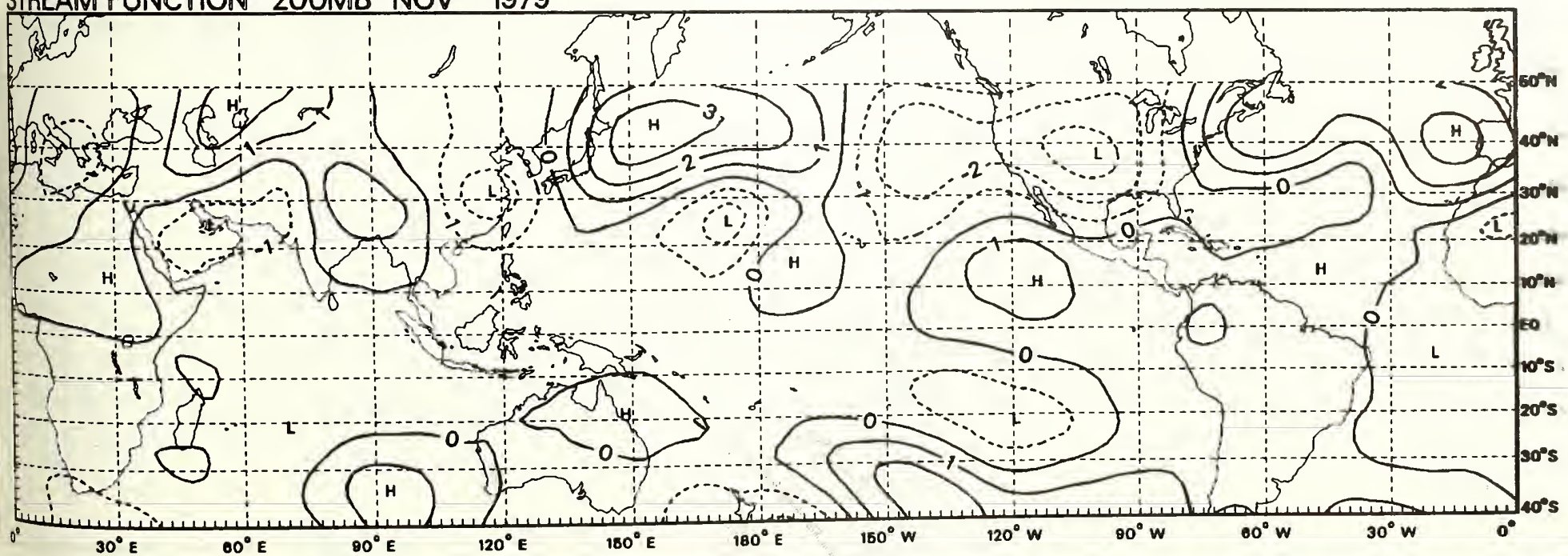
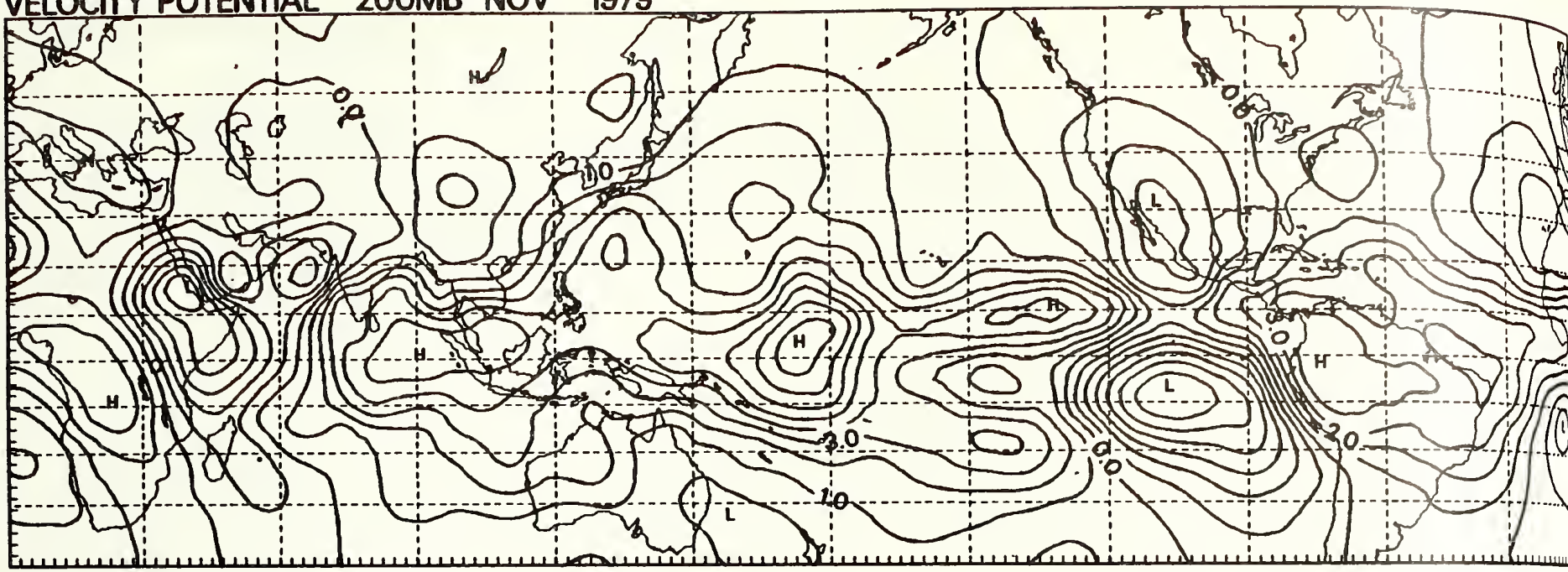
STREAM FUNCTION 200MB NOV 1979



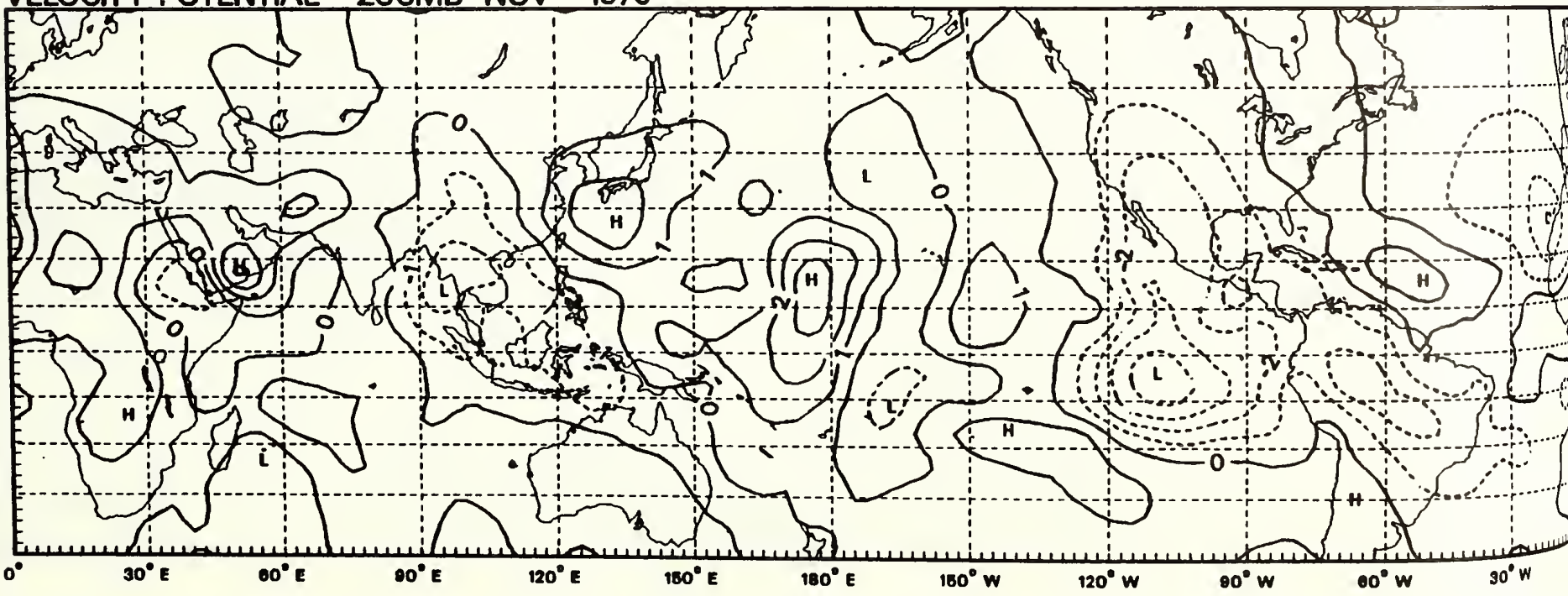
STREAM FUNCTION 200MB NOV 1979



VELOCITY POTENTIAL 200MB NOV 1979



VELOCITY POTENTIAL 200MB NOV 1979



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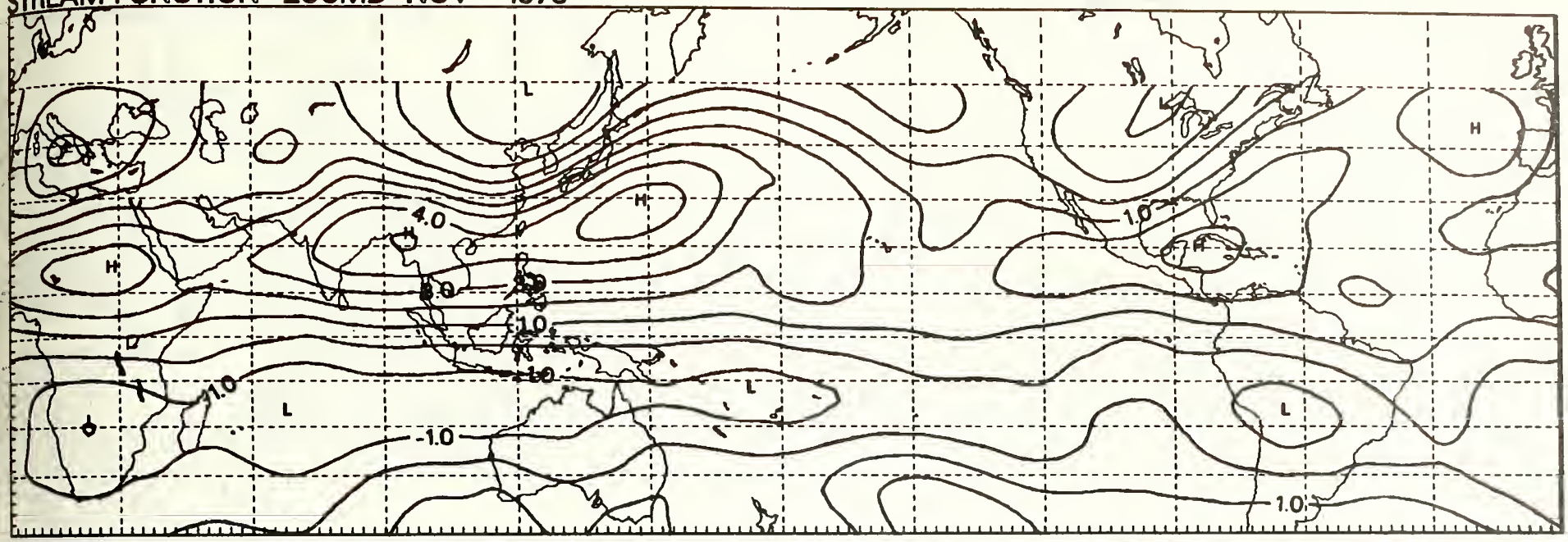
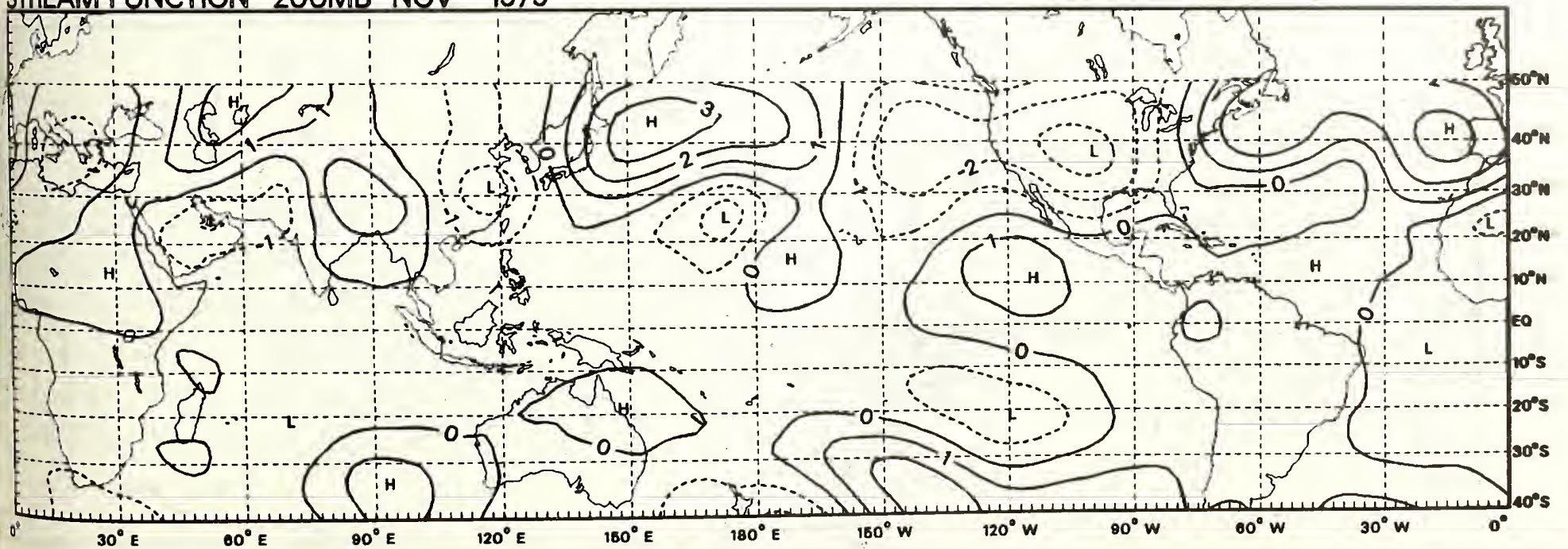
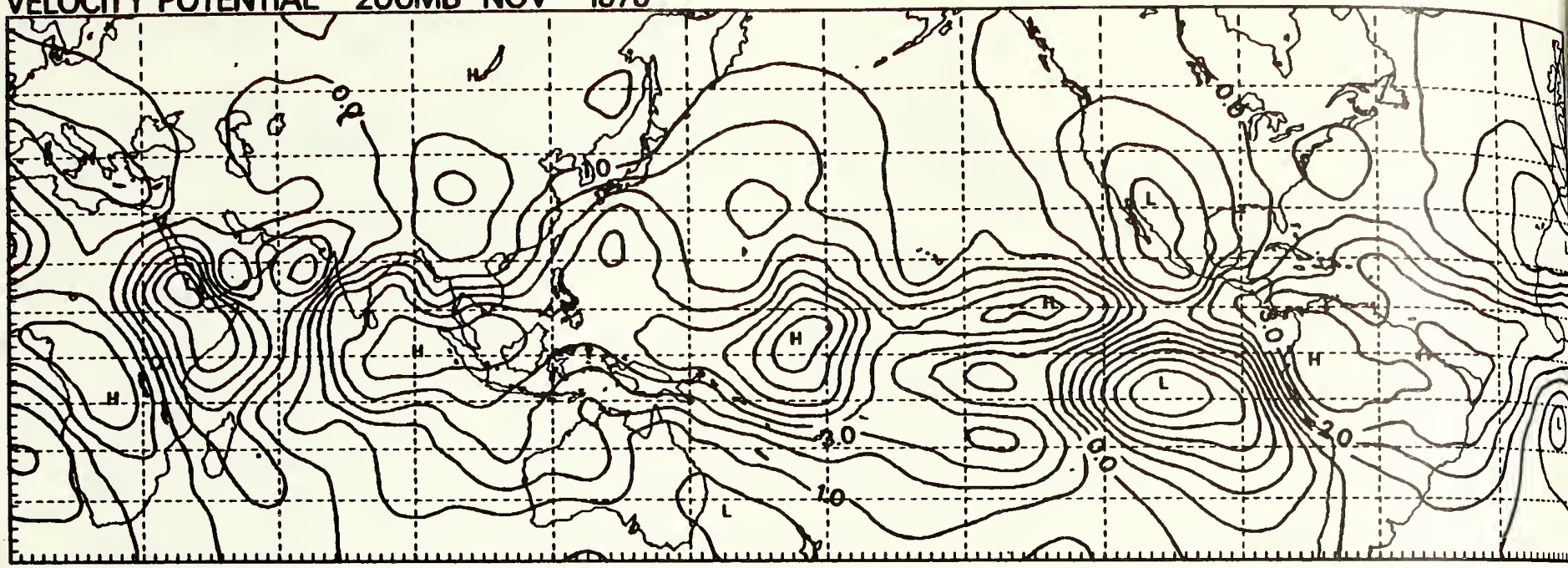


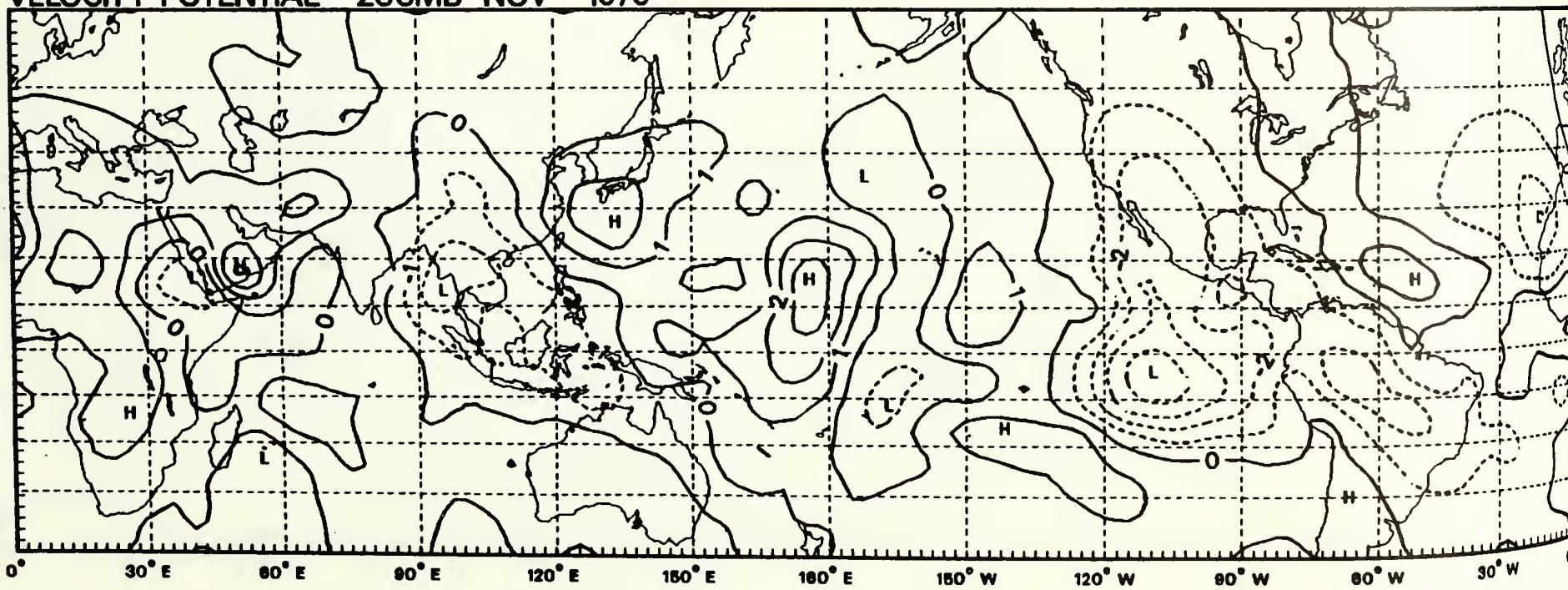
STREAM FUNCTION 200MB NOV 1979

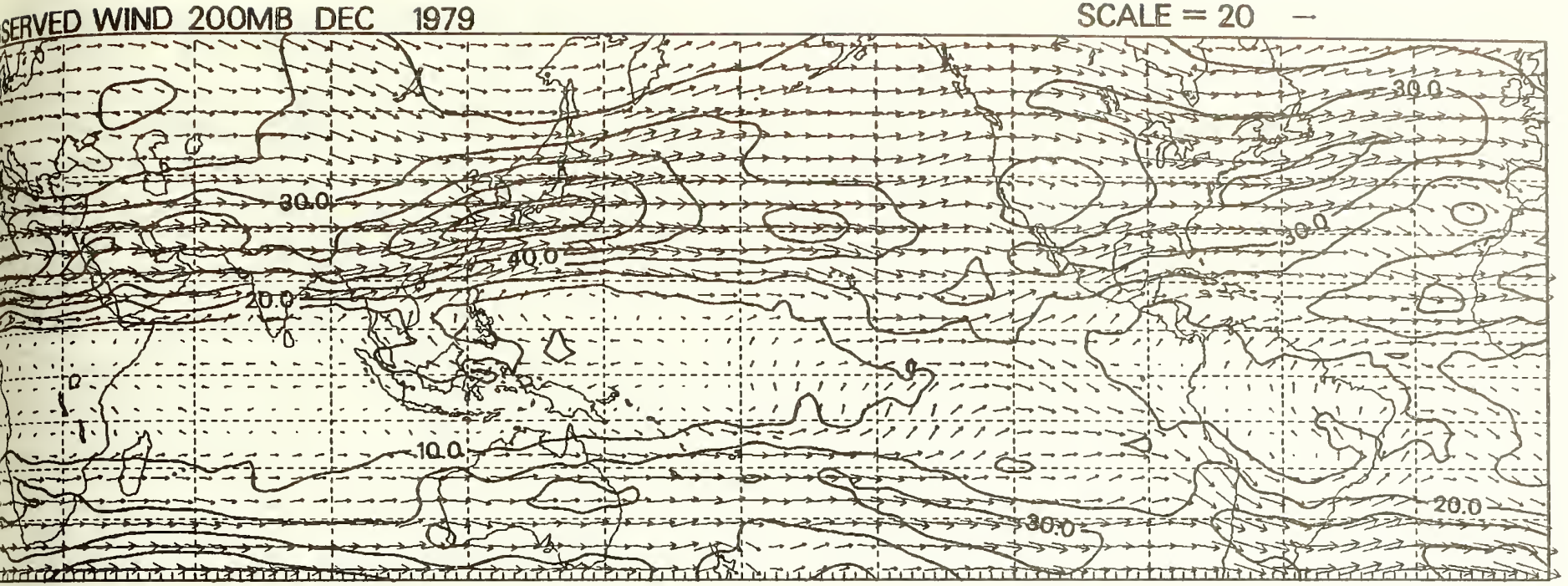


VELOCITY POTENTIAL 200MB NOV 1979



VELOCITY POTENTIAL 200MB NOV 1979




SERVED WIND 200MB DEC 1979
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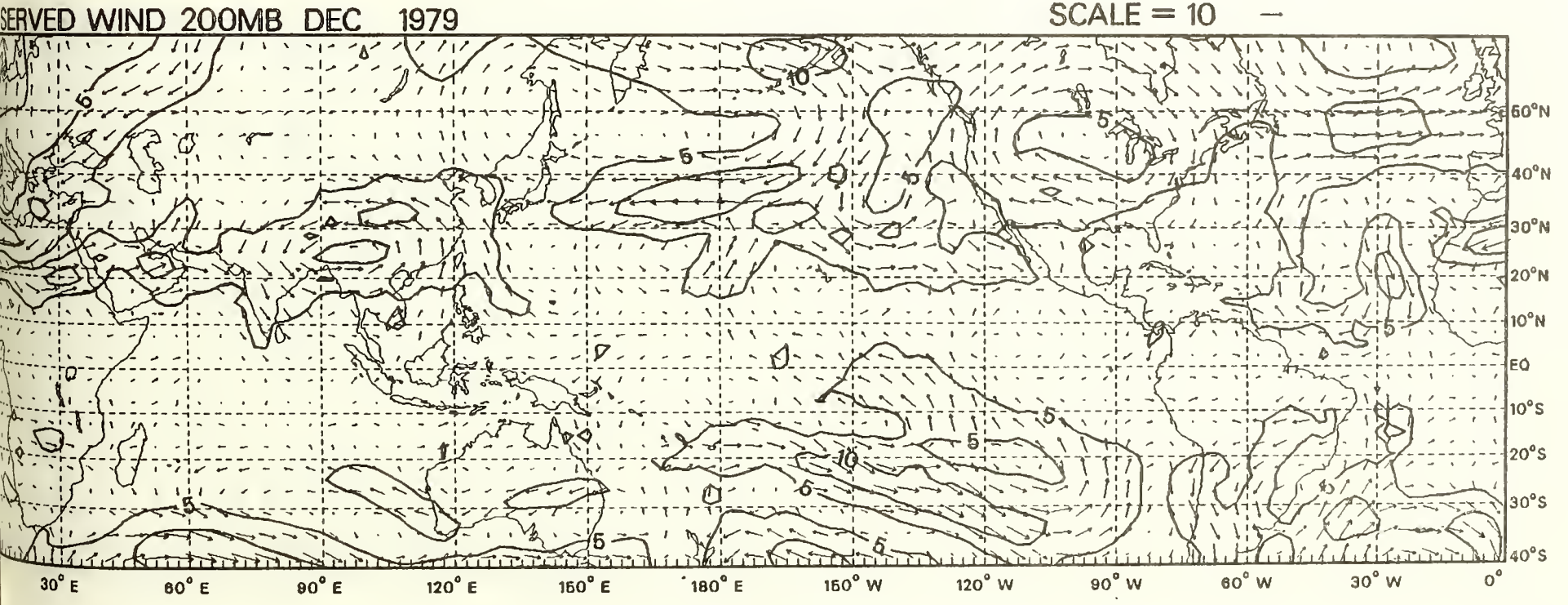
30.0
30.0
20.0


SERVED WIND 200MB DEC 1979
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30°N
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10°N
EQ
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20°S
30°S
40°S
30° E
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60° W
30° W
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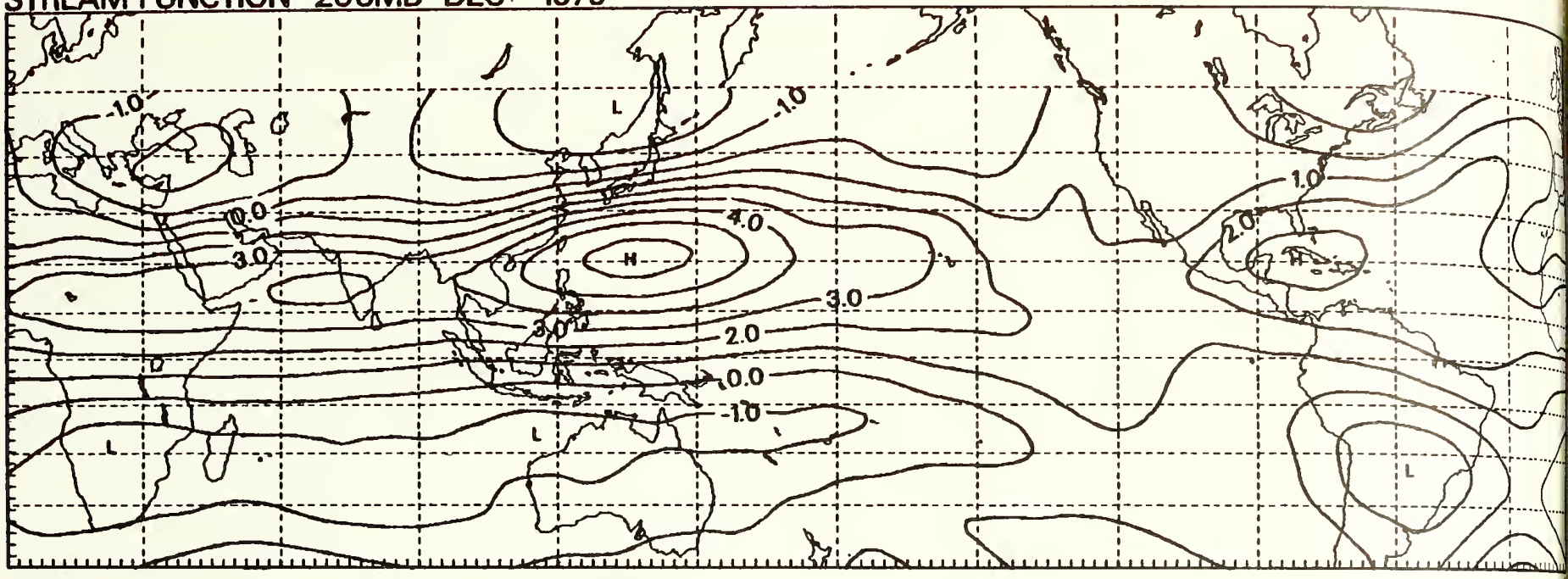
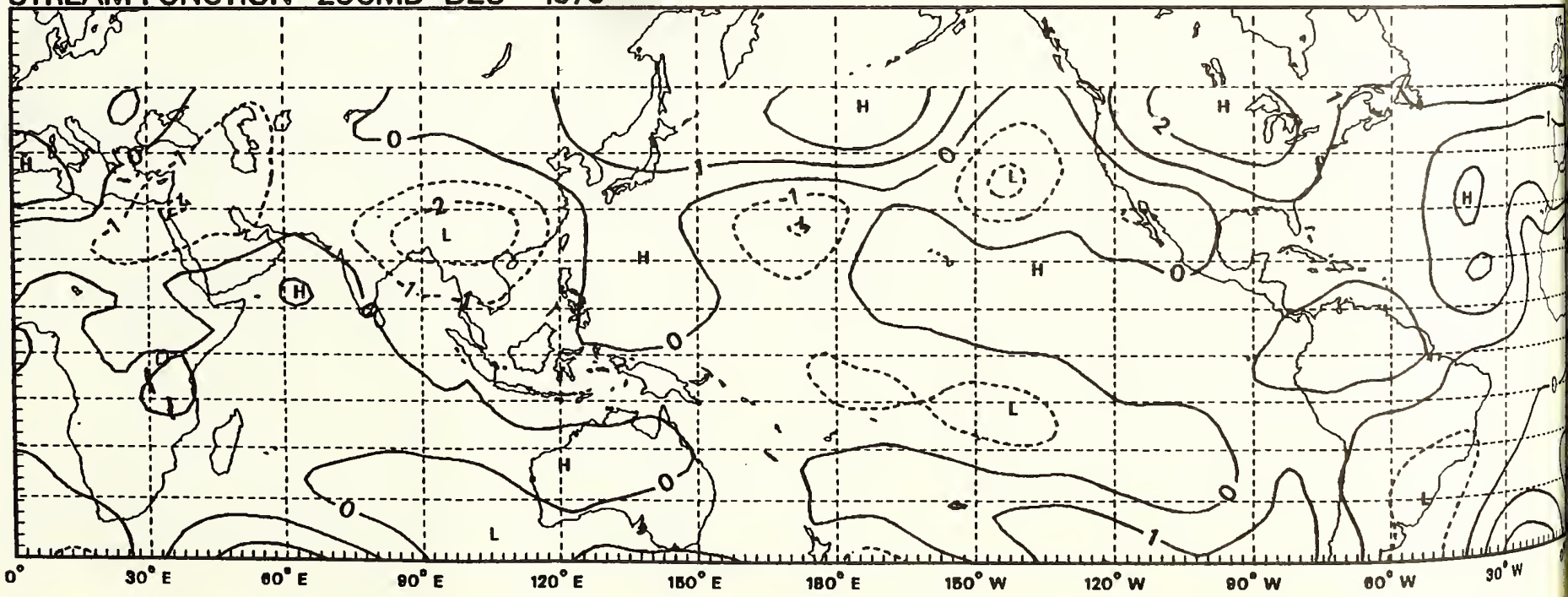
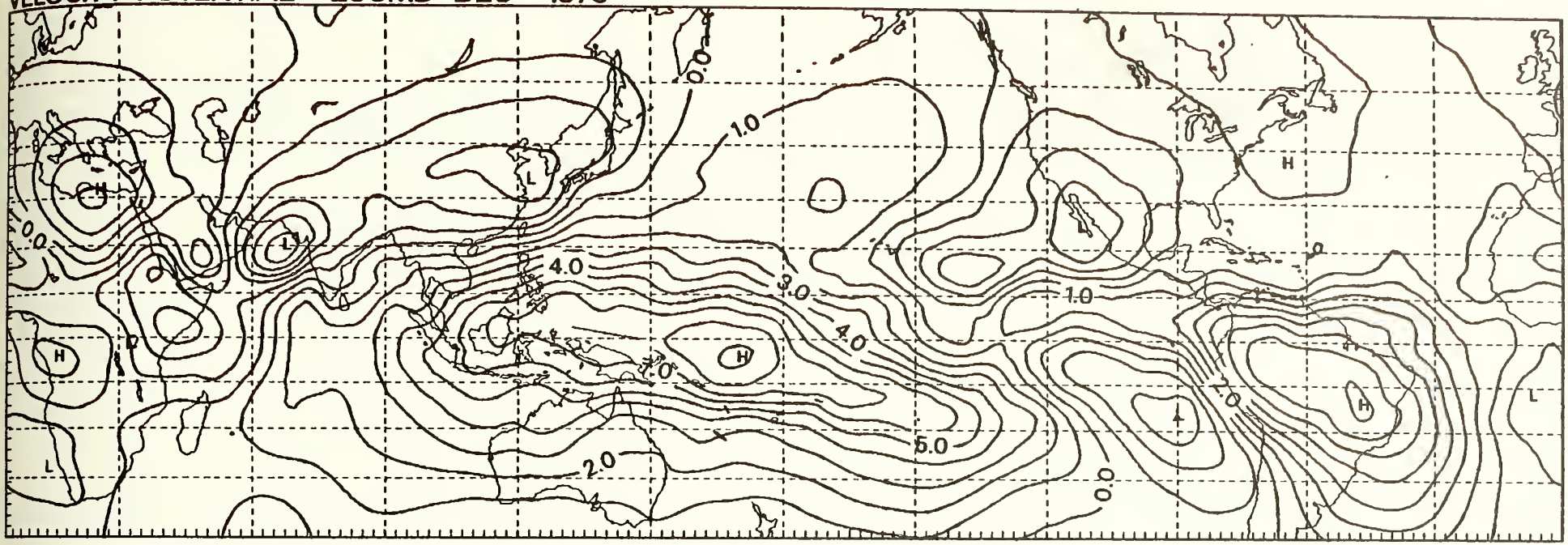
STREAM FUNCTION 200MB DEC 1979



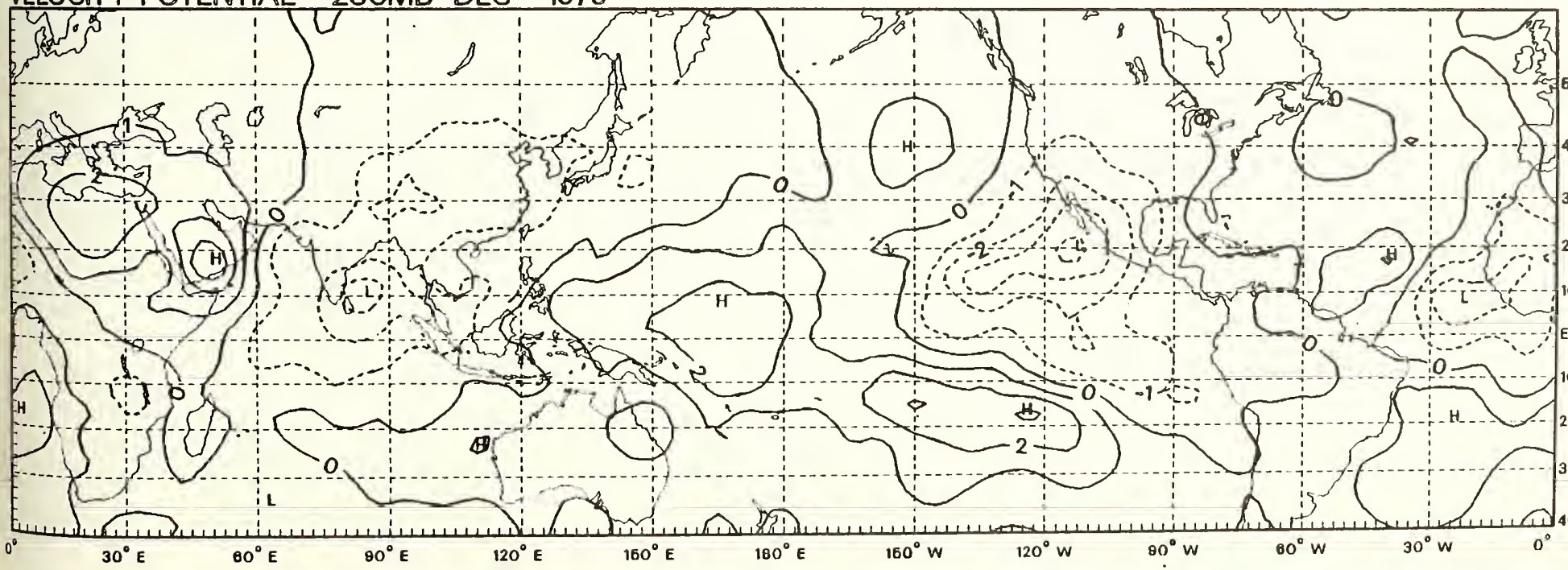
STREAM FUNCTION 200MB DEC 1979



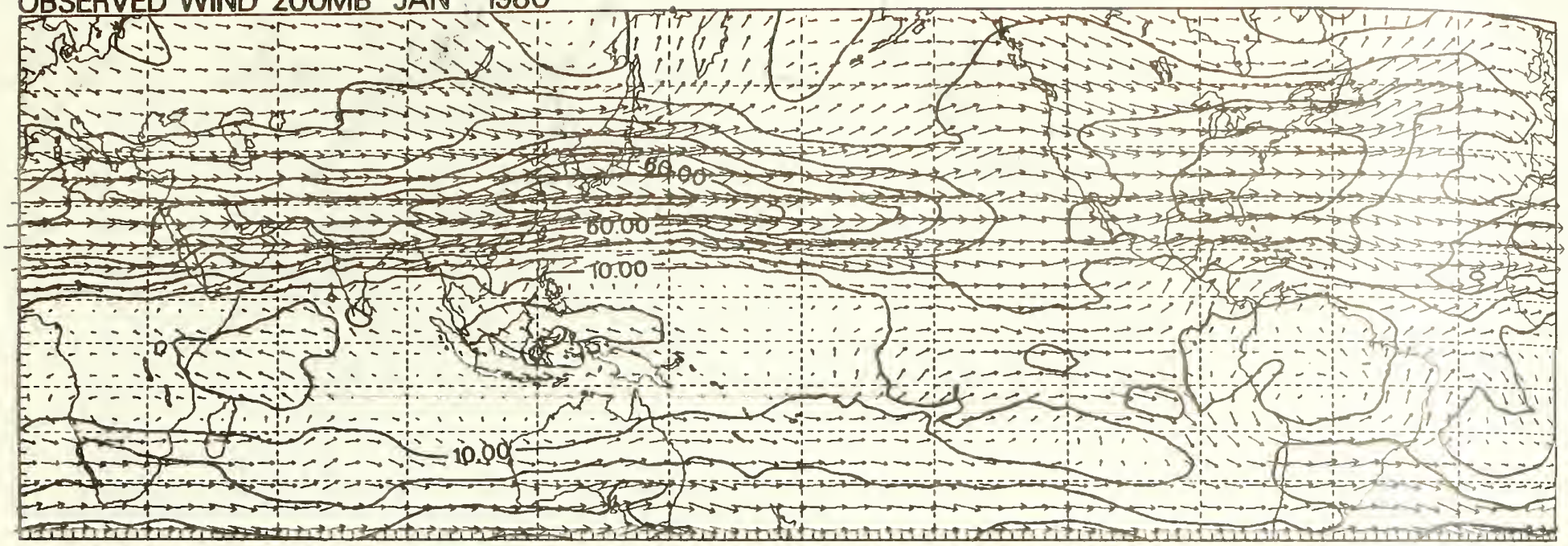
VELOCITY POTENTIAL 200MB DEC 1979



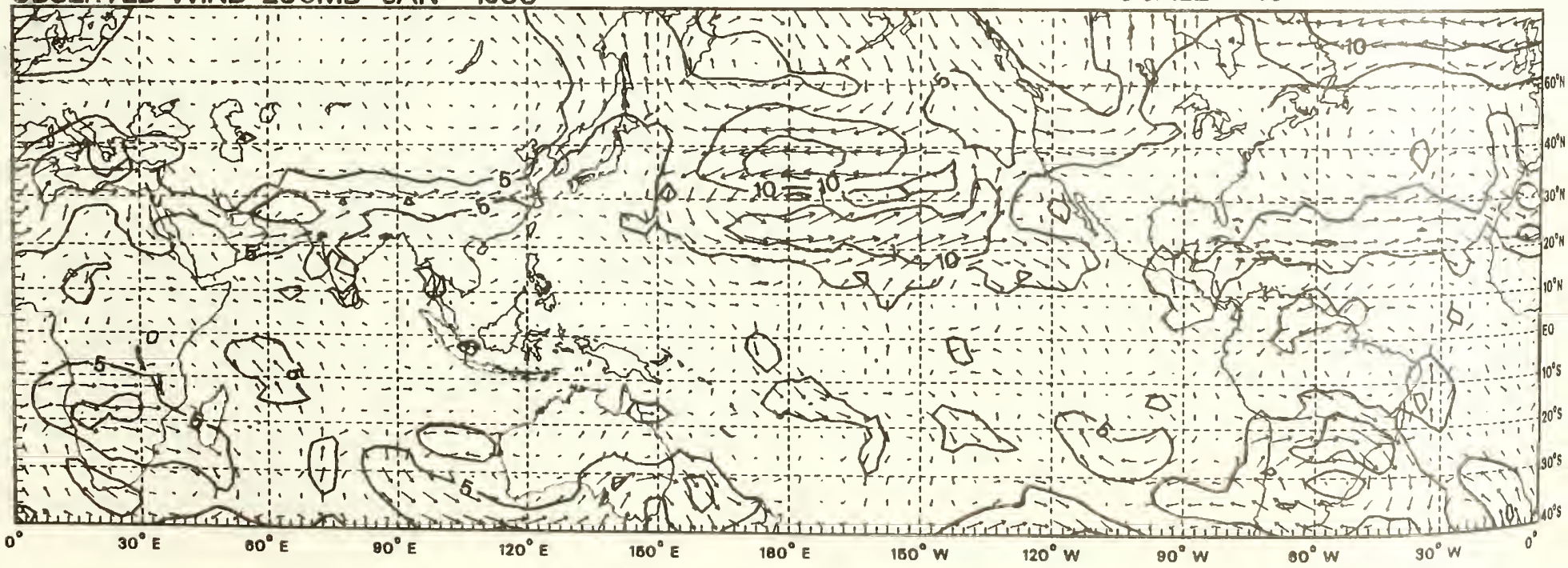
VELOCITY POTENTIAL 200MB DEC 1979



OBSERVED WIND 200MB JAN 1980 SCALE = 20



OBSERVED WIND 200MB JAN 1980 SCALE = 10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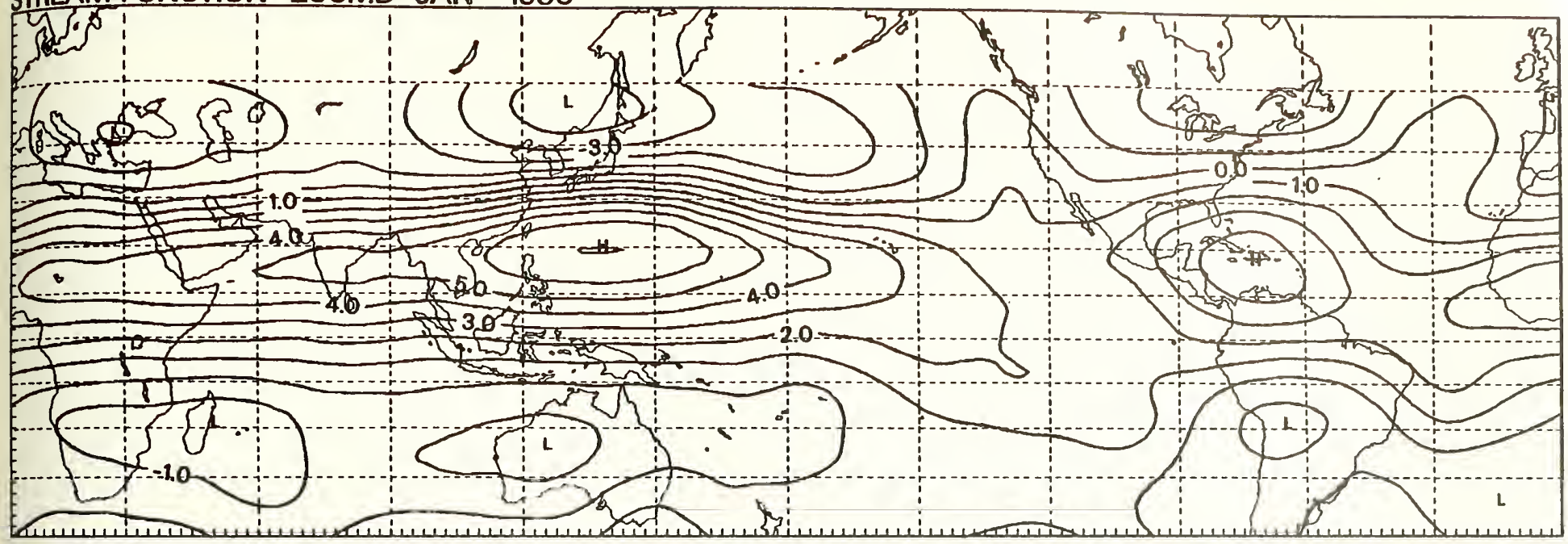
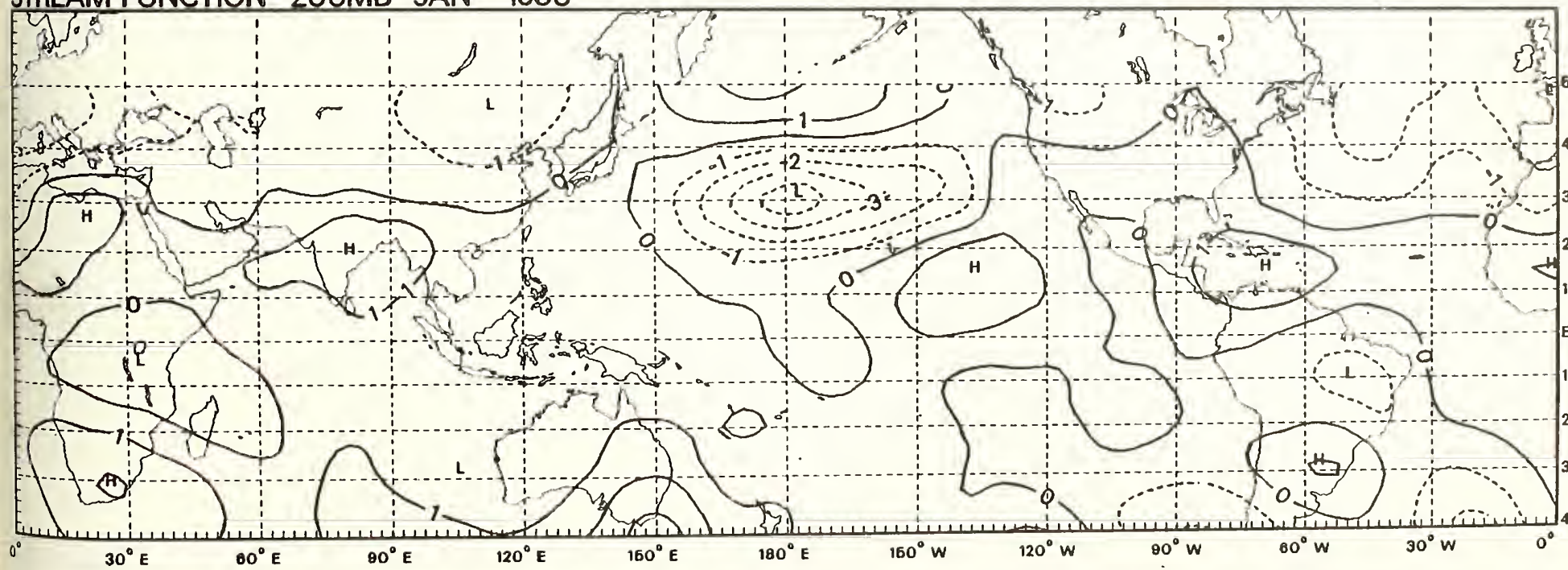
5

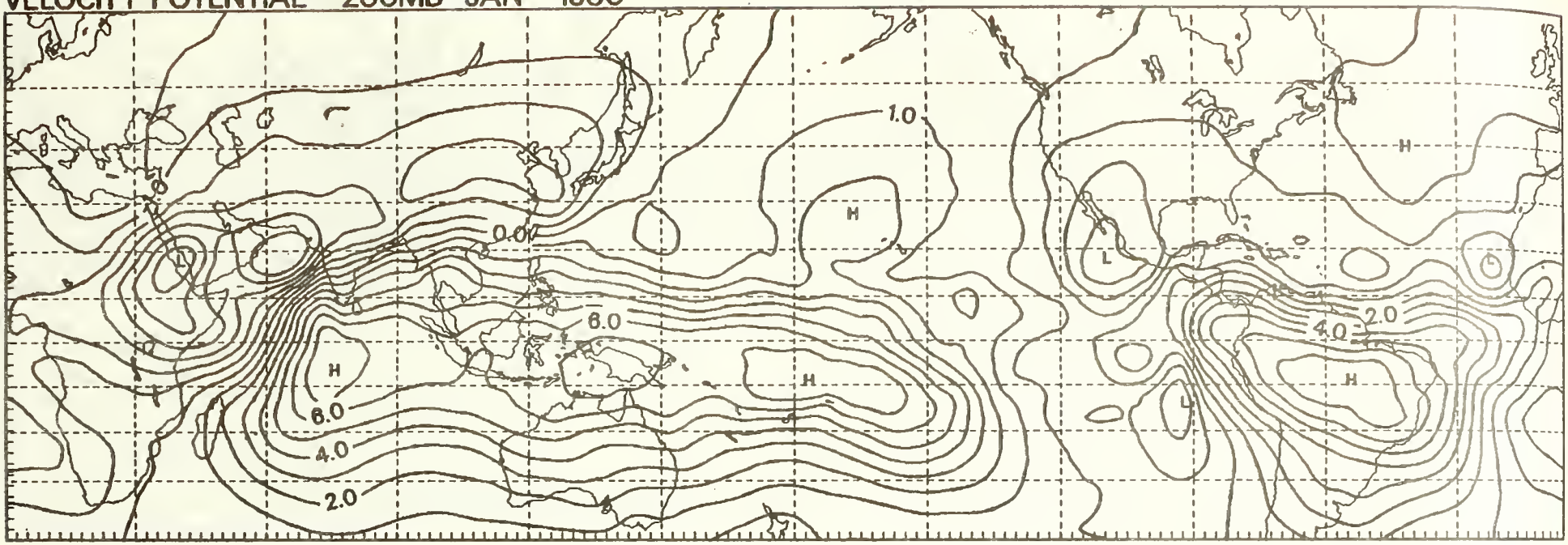
STREAM FUNCTION 200MB JAN 1980



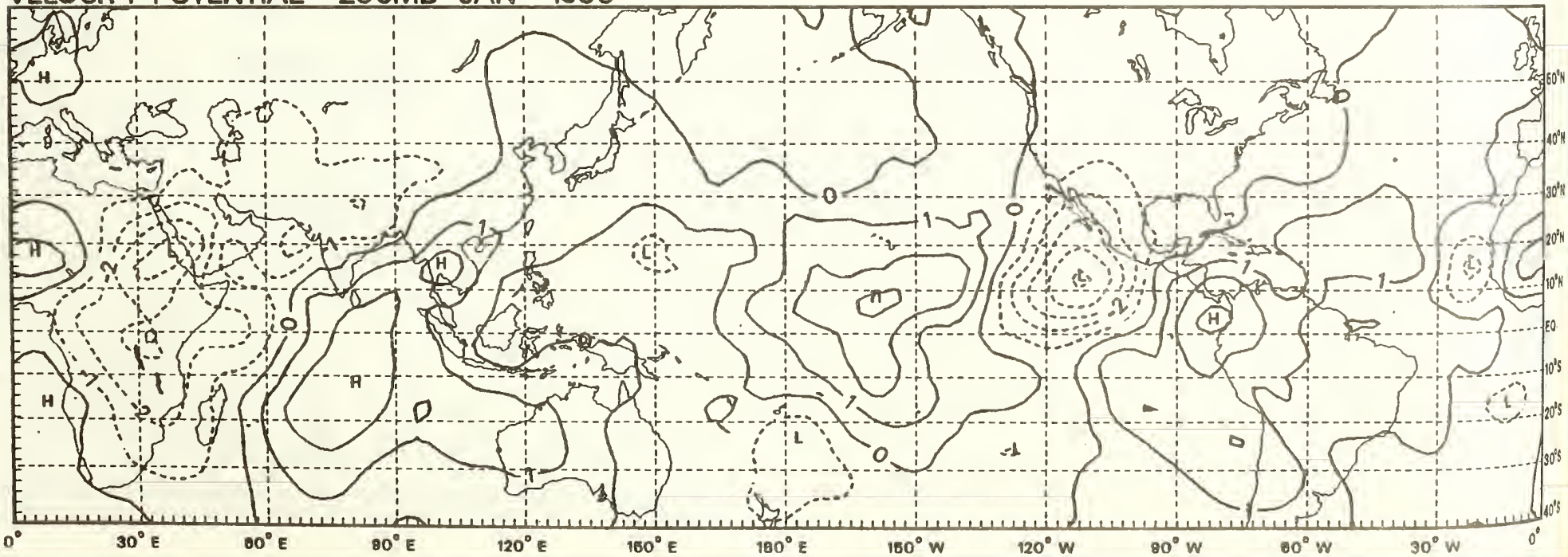
STREAM FUNCTION 200MB JAN 1980



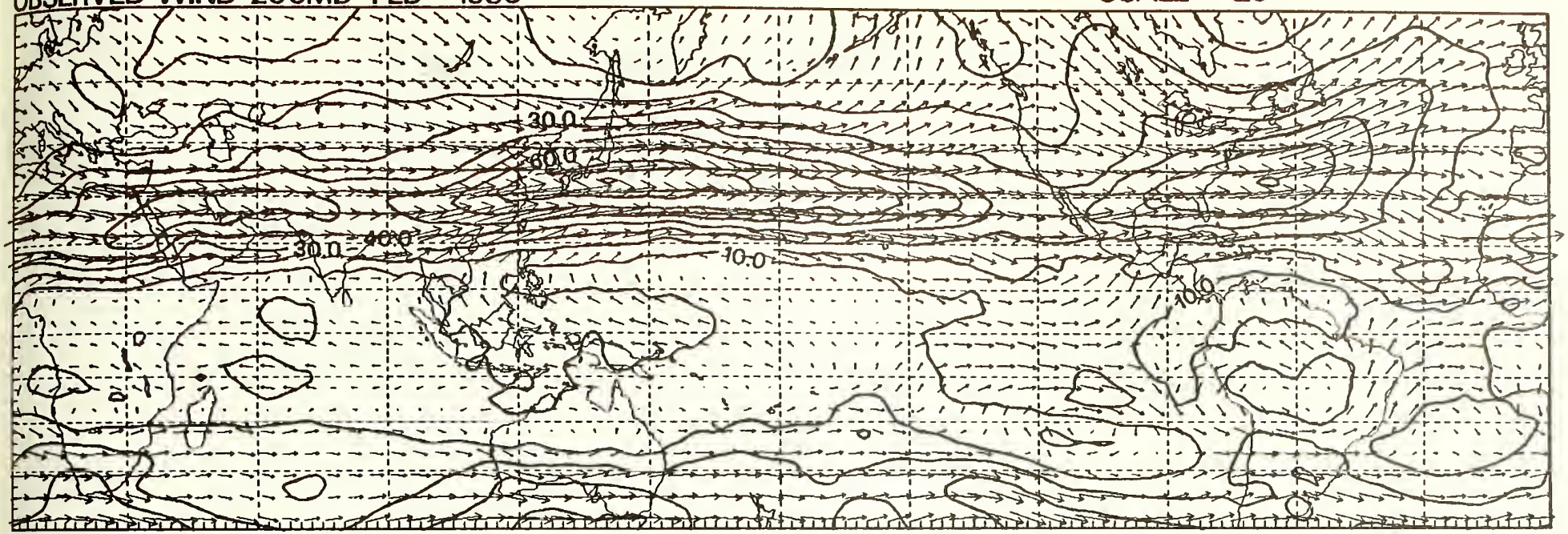
VELOCITY POTENTIAL 200MB JAN 1980



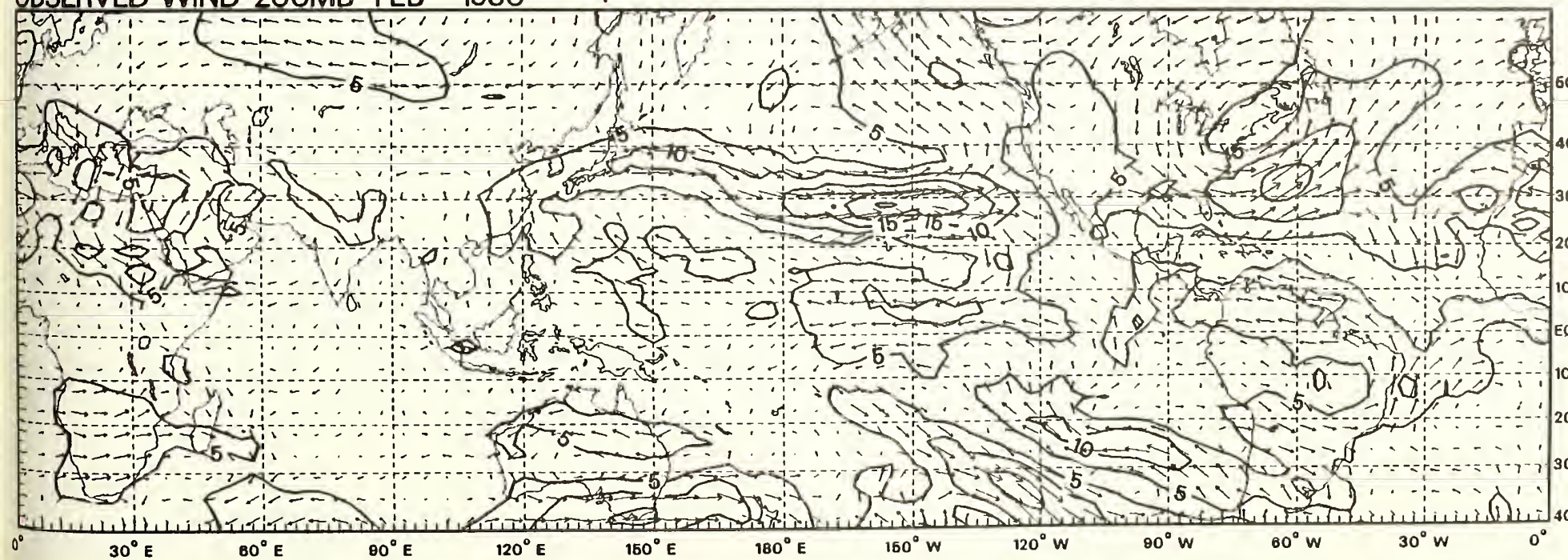
VELOCITY POTENTIAL 200MB JAN 1980



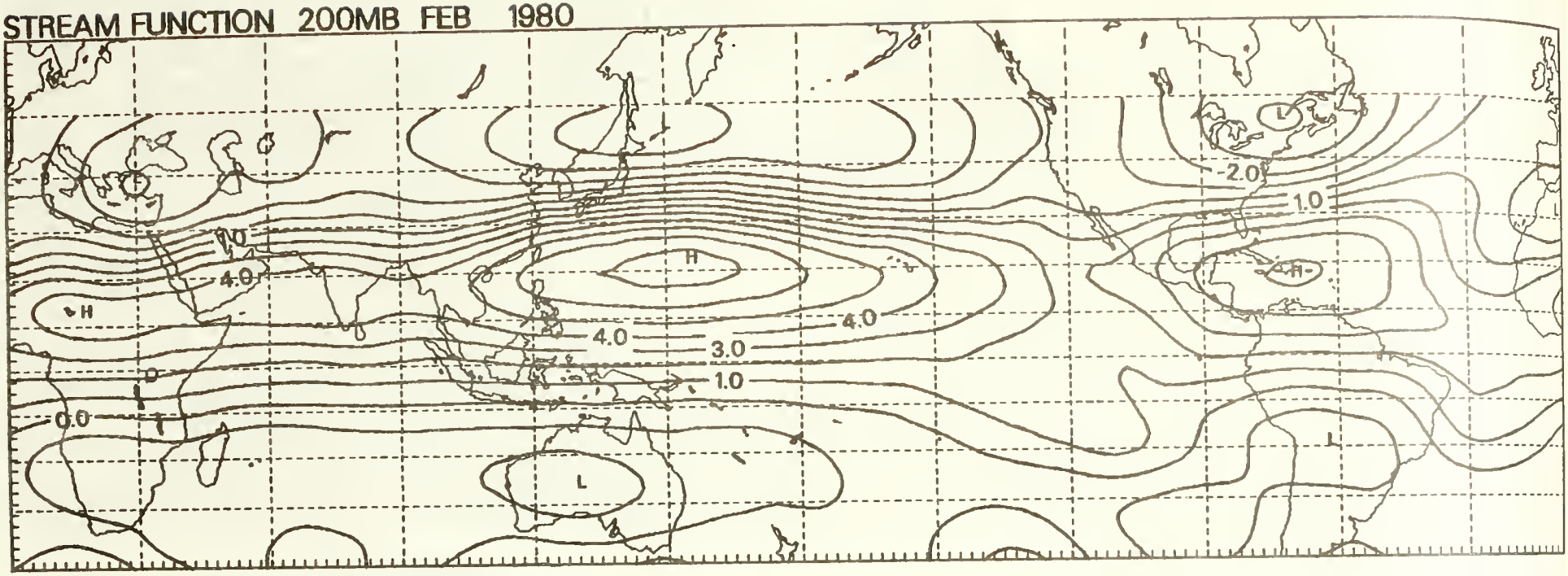
OBSERVED WIND 200MB FEB 1980 SCALE = 20



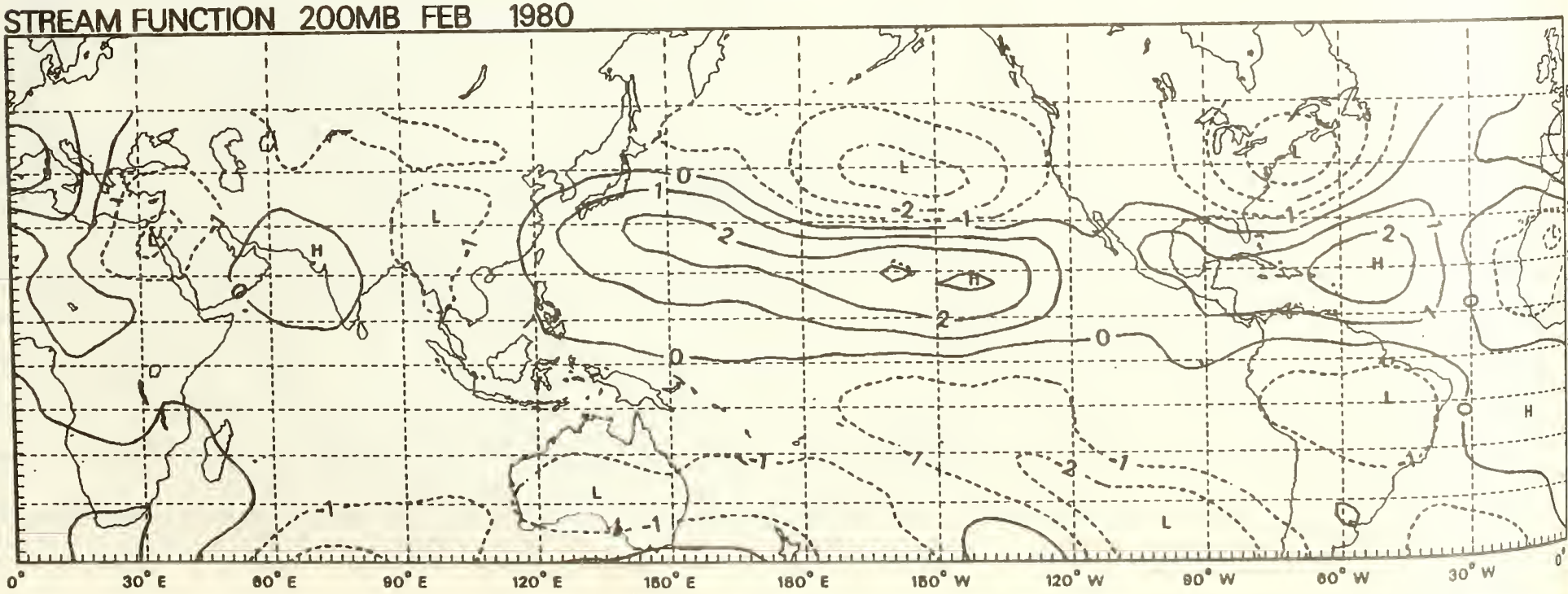
OBSERVED WIND 200MB FEB 1980 SCALE = 10



STREAM FUNCTION 200MB FEB 1980



STREAM FUNCTION 200MB FEB 1980



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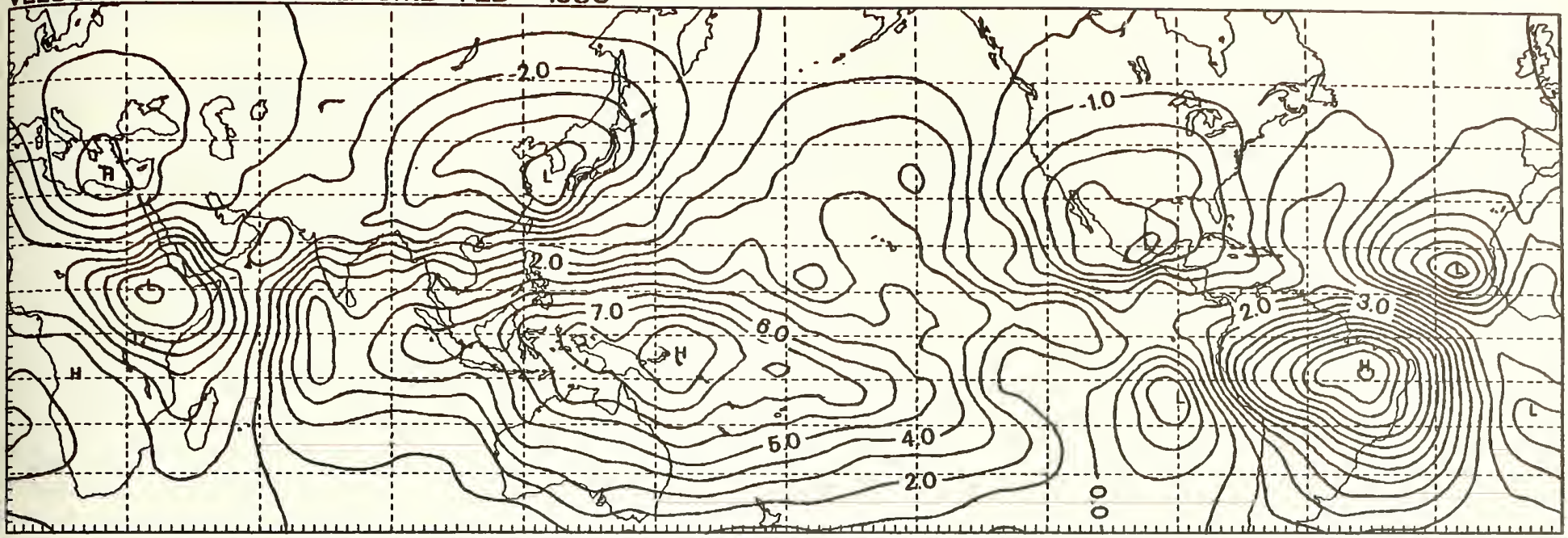
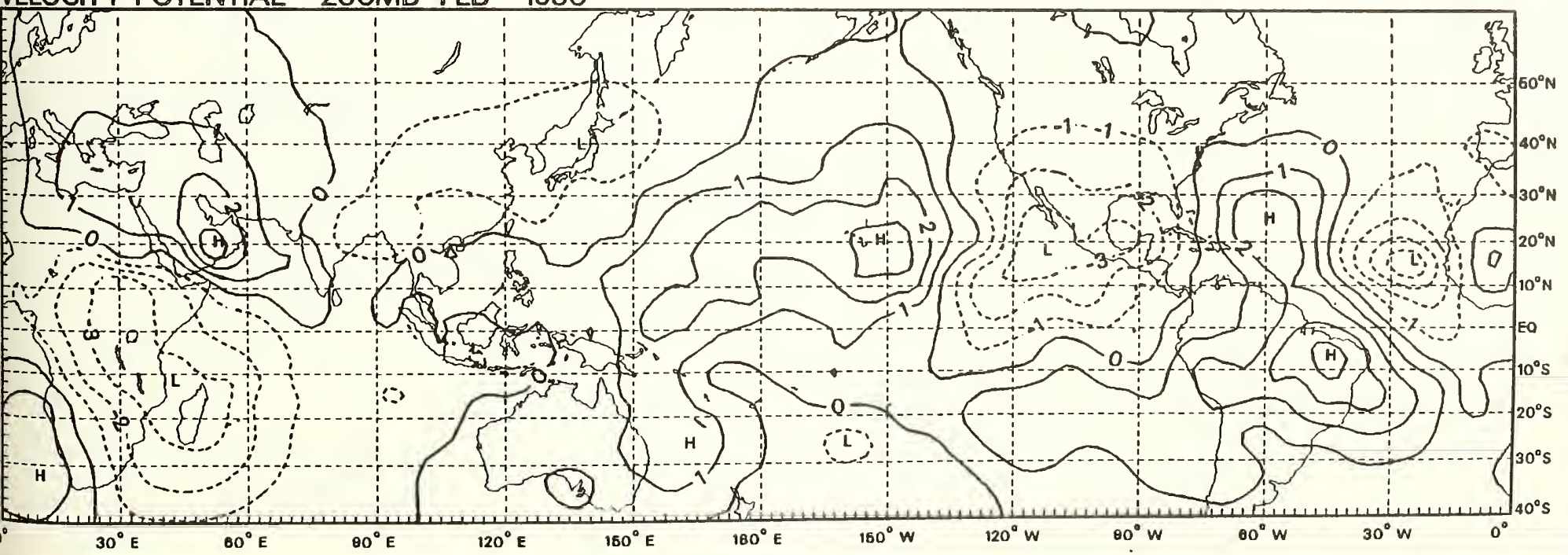


VELOCITY POTENTIAL 200MB FEB 1980



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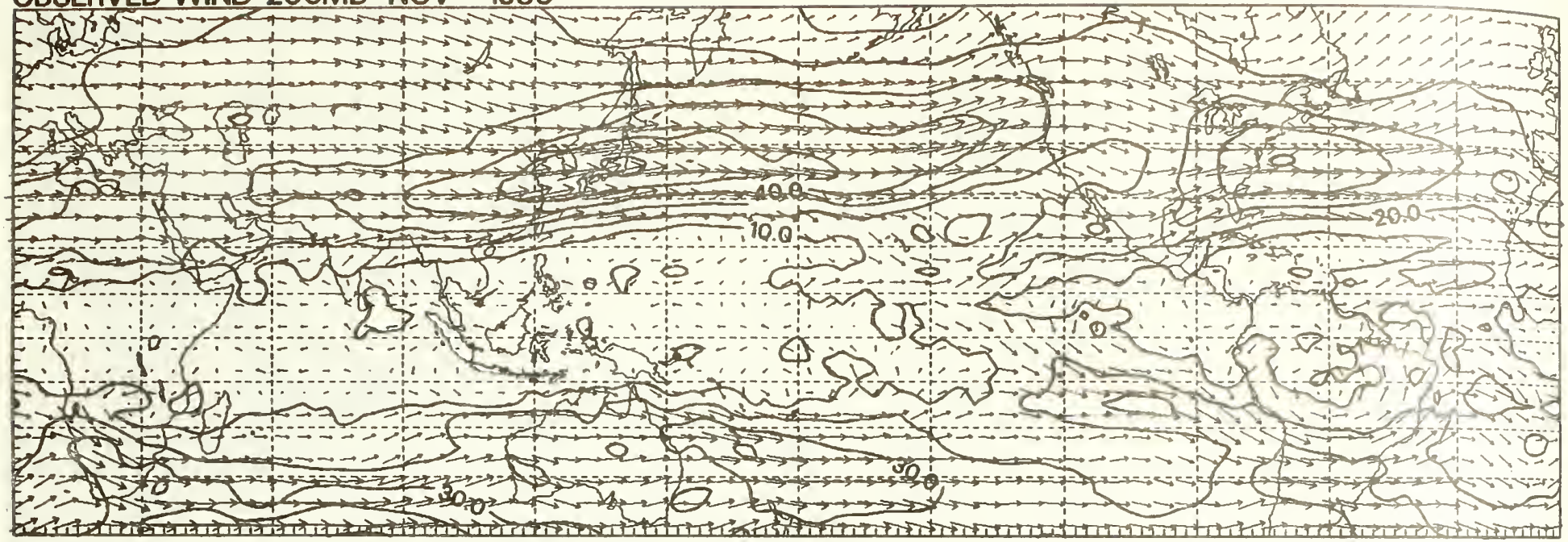
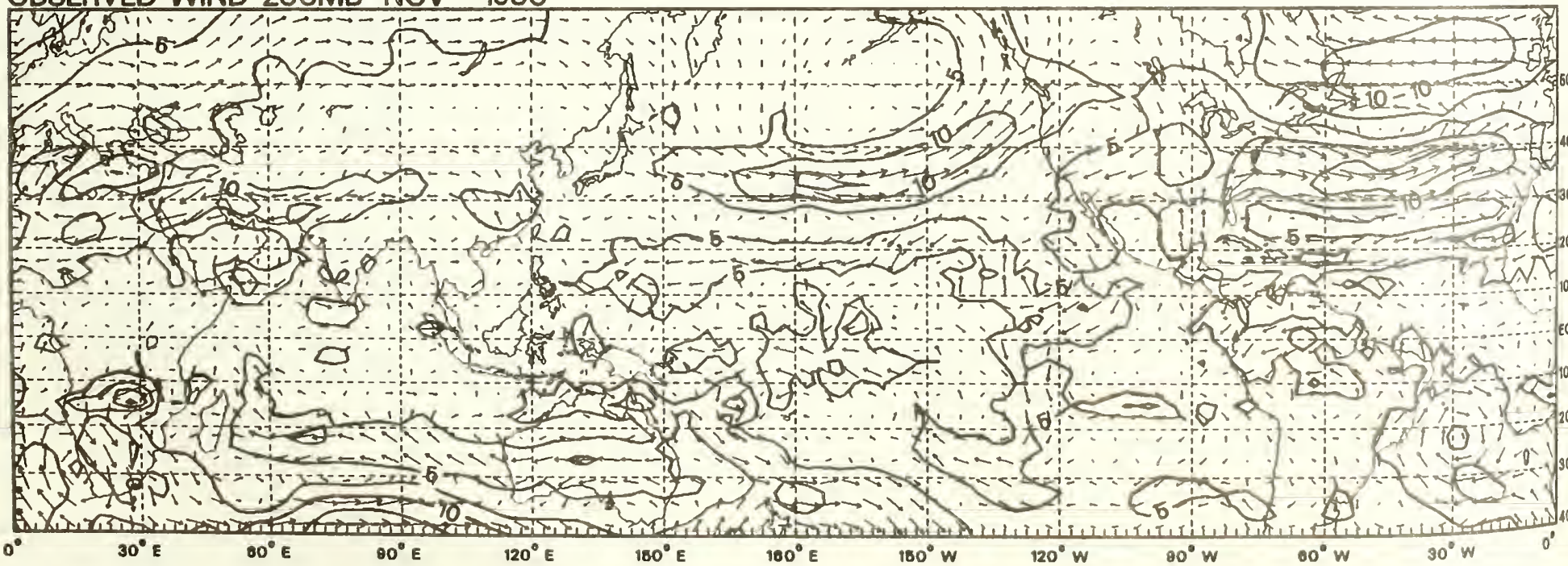
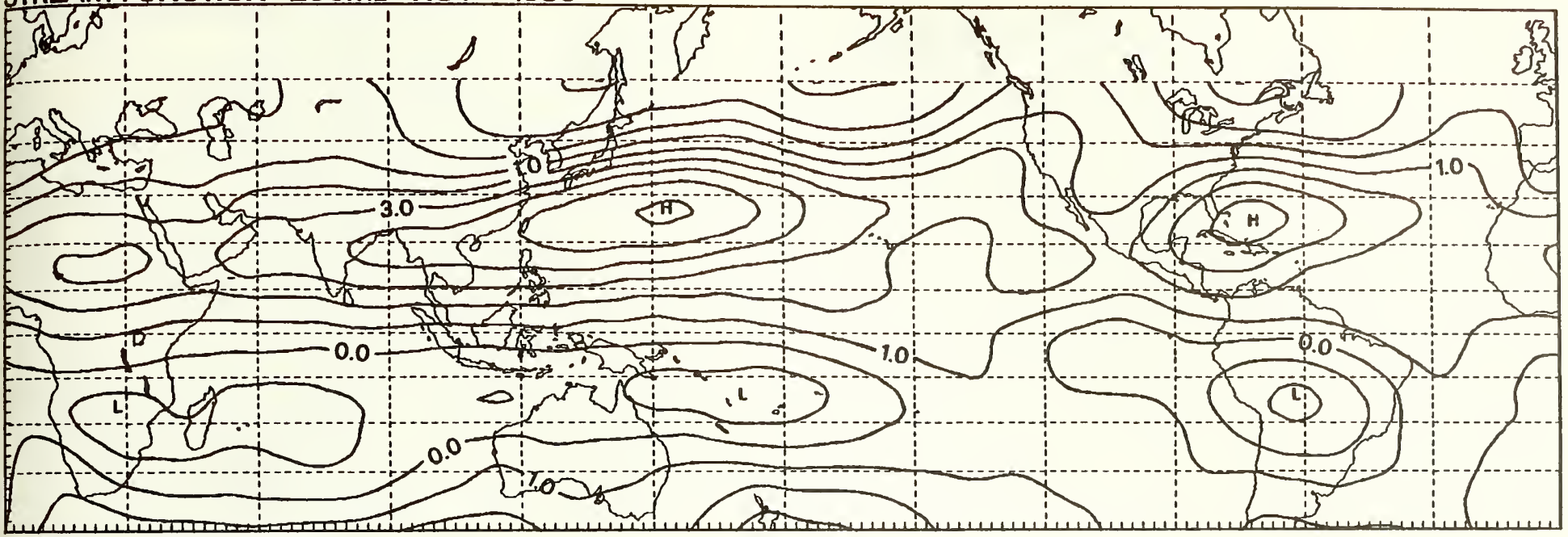


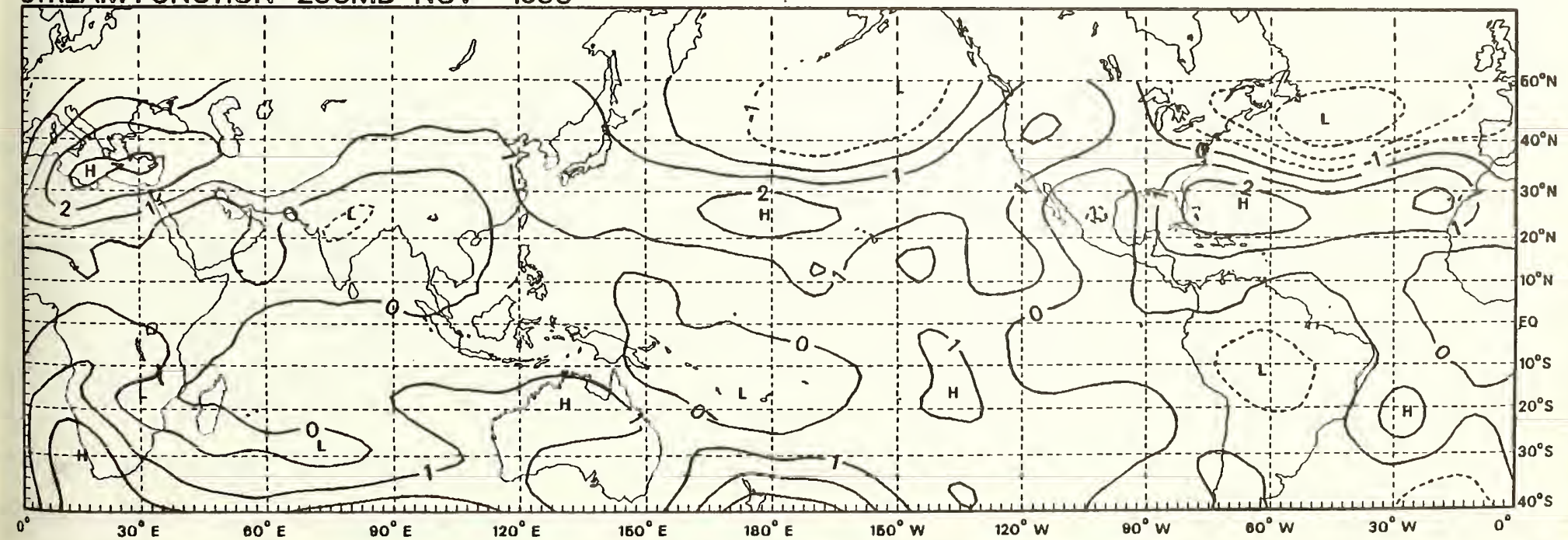
OBSERVED WIND 200MB NOV 1980 SCALE = 10



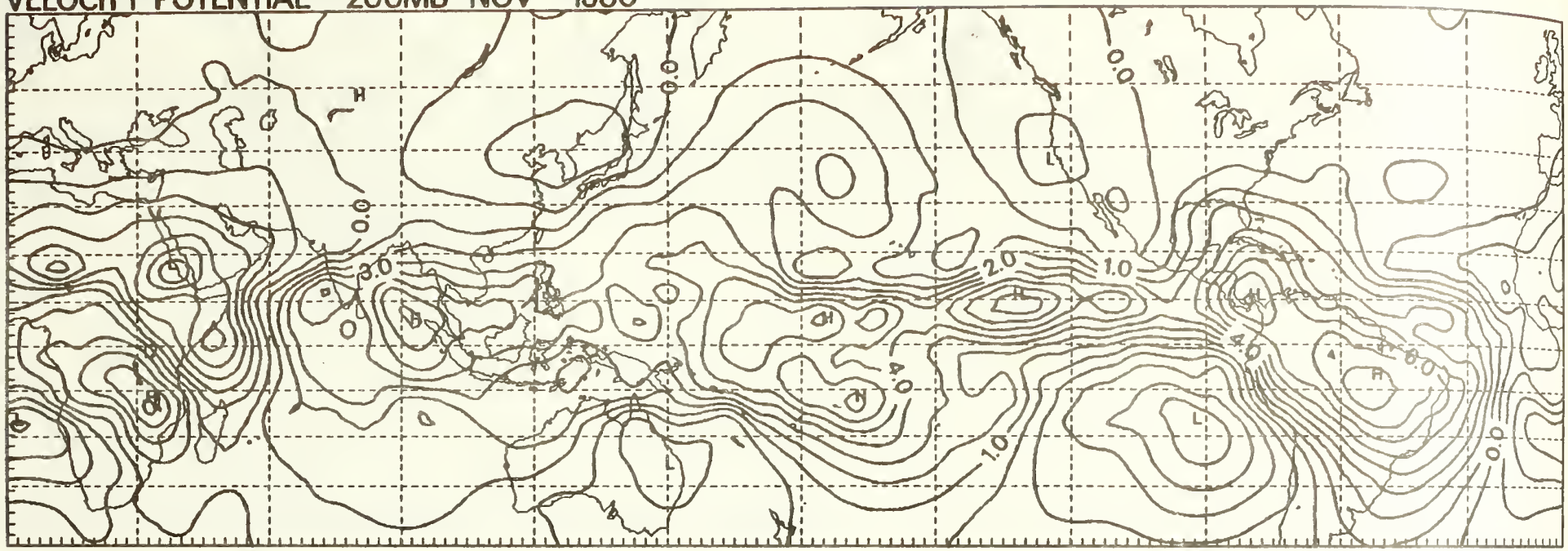
STREAM FUNCTION 200MB NOV 1980



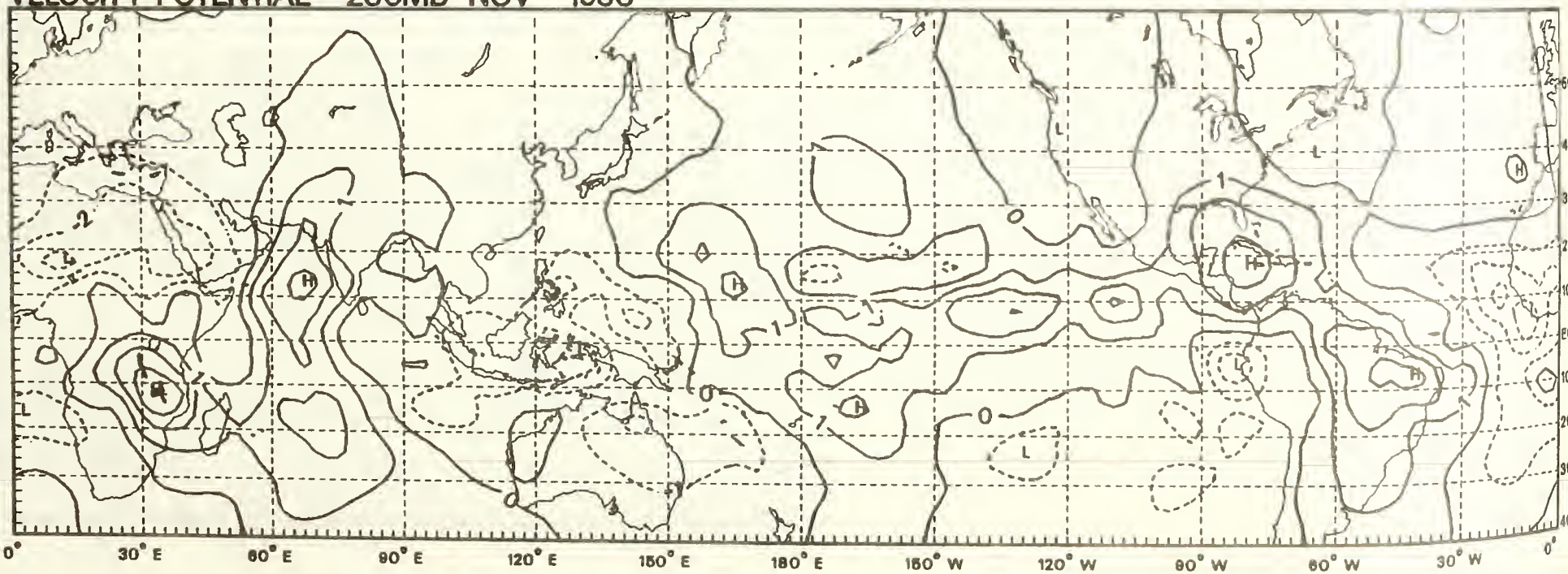
STREAM FUNCTION 200MB NOV 1980

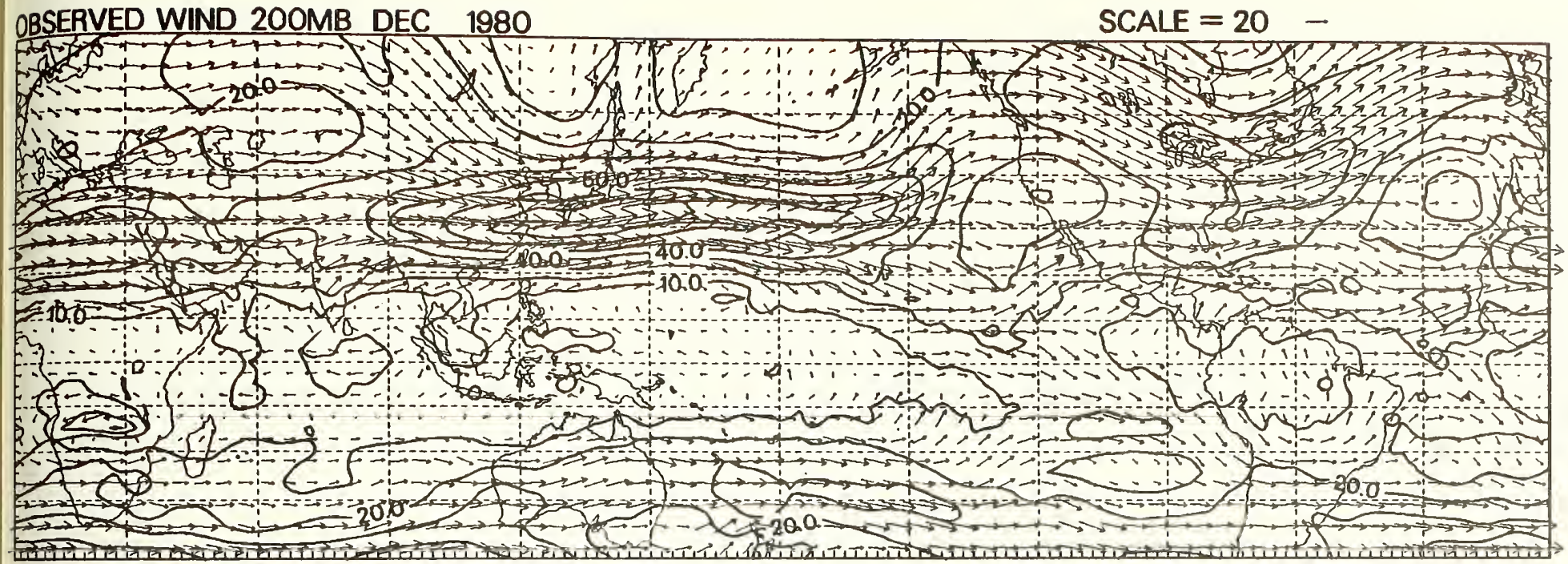


VELOCITY POTENTIAL 200MB NOV 1980



VELOCITY POTENTIAL 200MB NOV 1980




OBSERVED WIND 200MB DEC 1980
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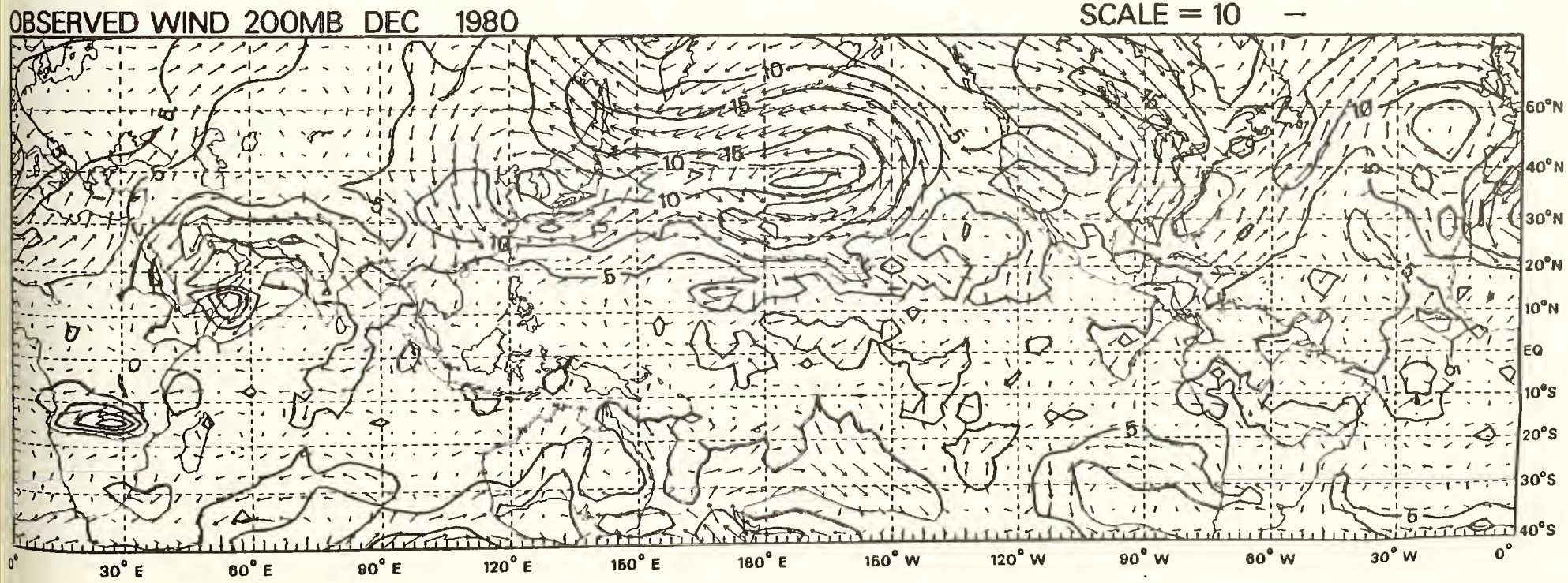
OBSERVED WIND 200MB DEC 1980
SCALE = 10
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30°N
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EQ
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40°S
0°
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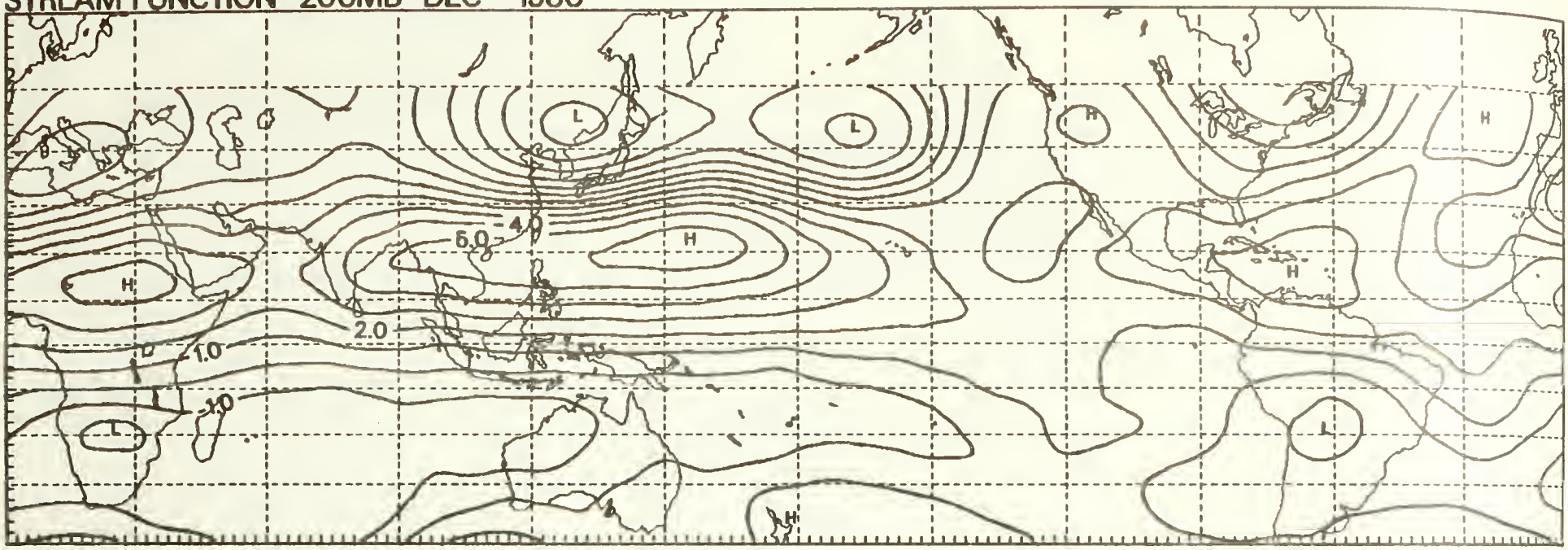
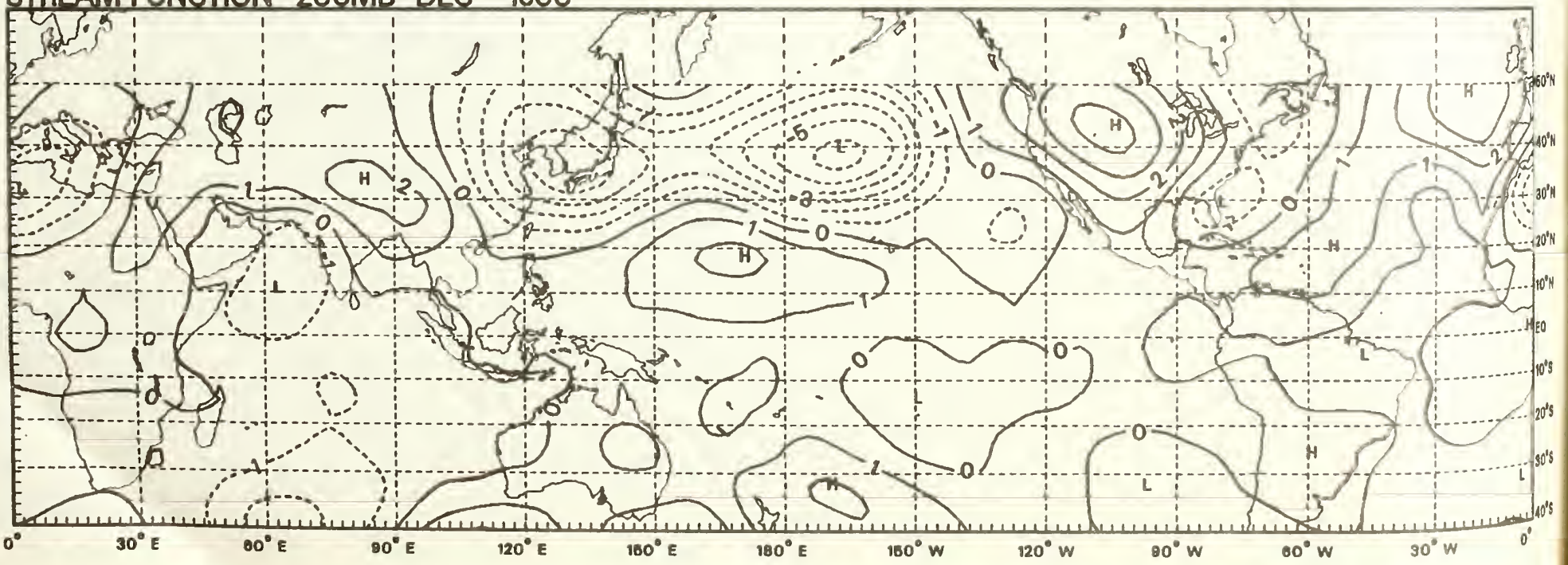
60° W
30° W
0°

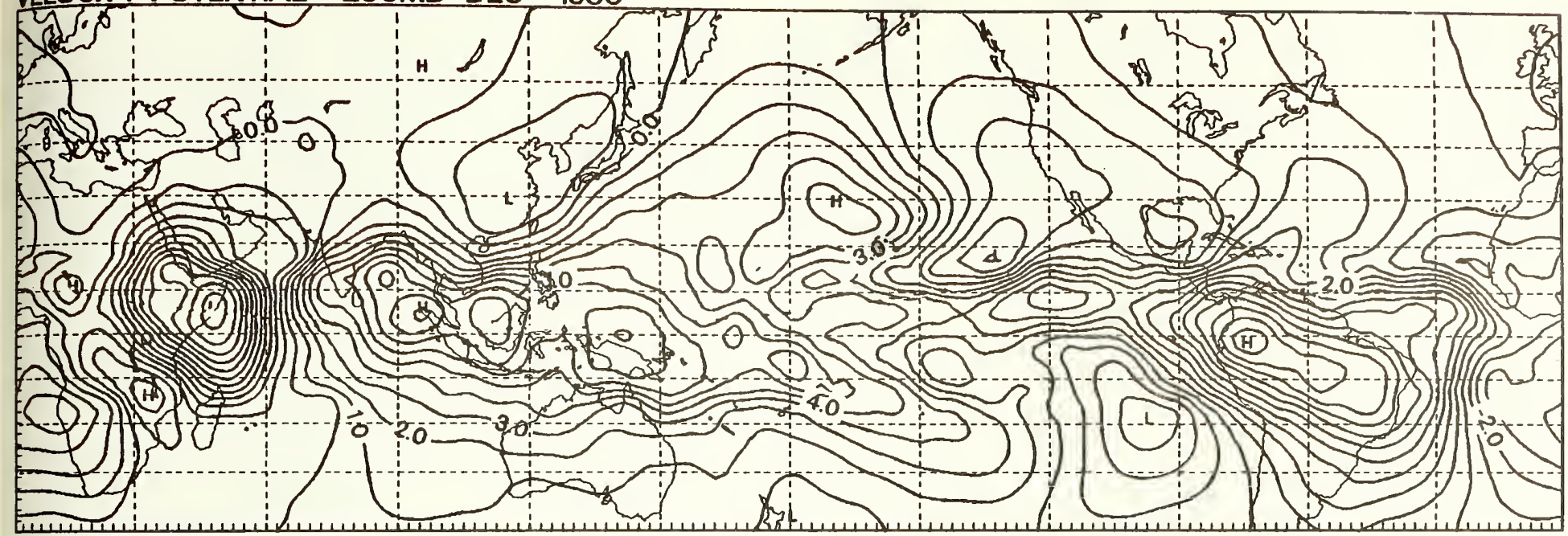
STREAM FUNCTION 200MB DEC 1980



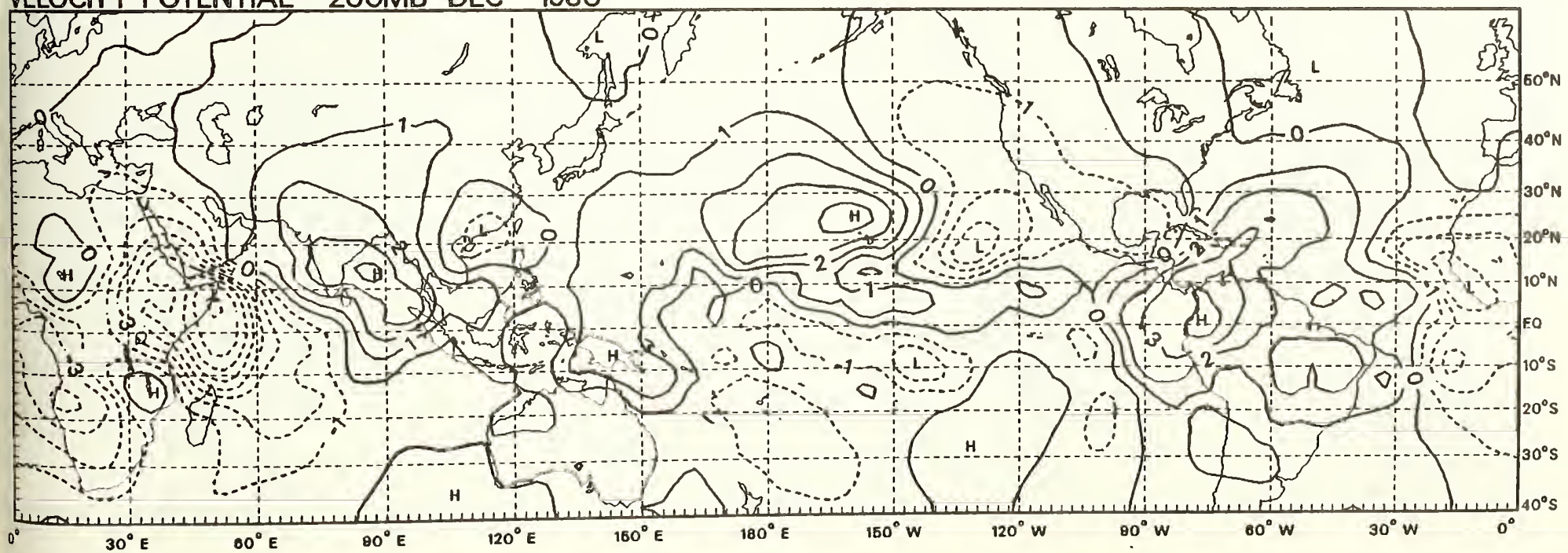
STREAM FUNCTION 200MB DEC 1980



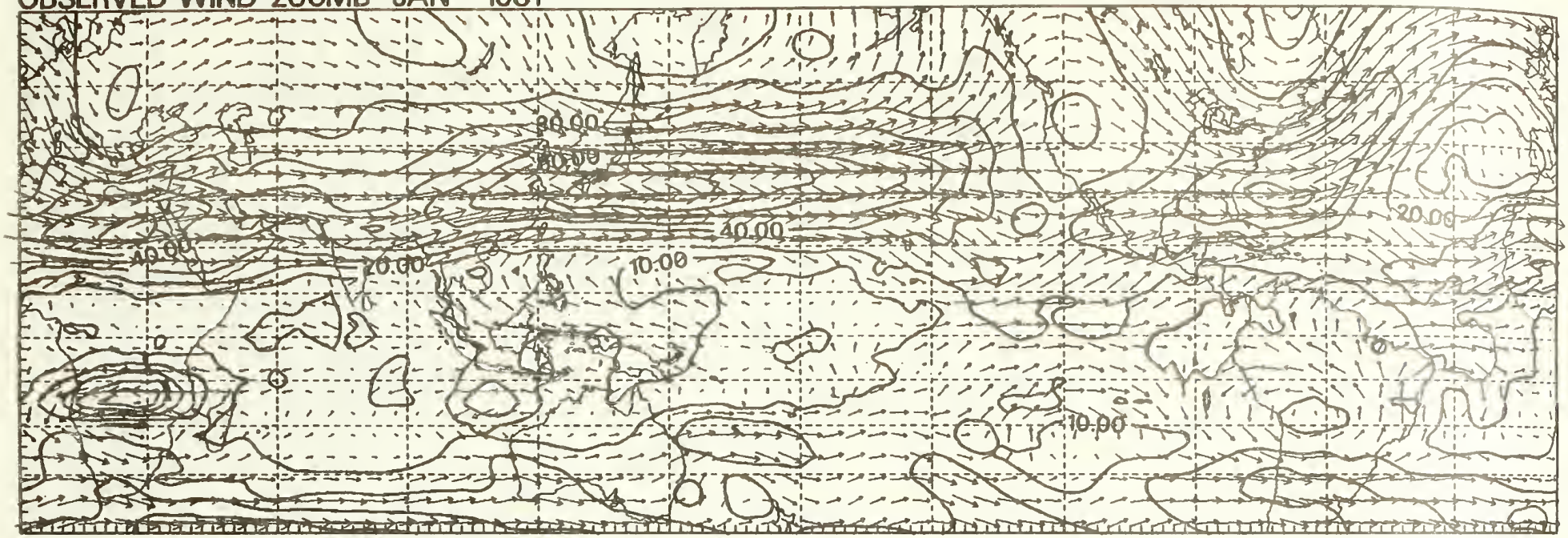
VELOCITY POTENTIAL 200MB DEC 1980



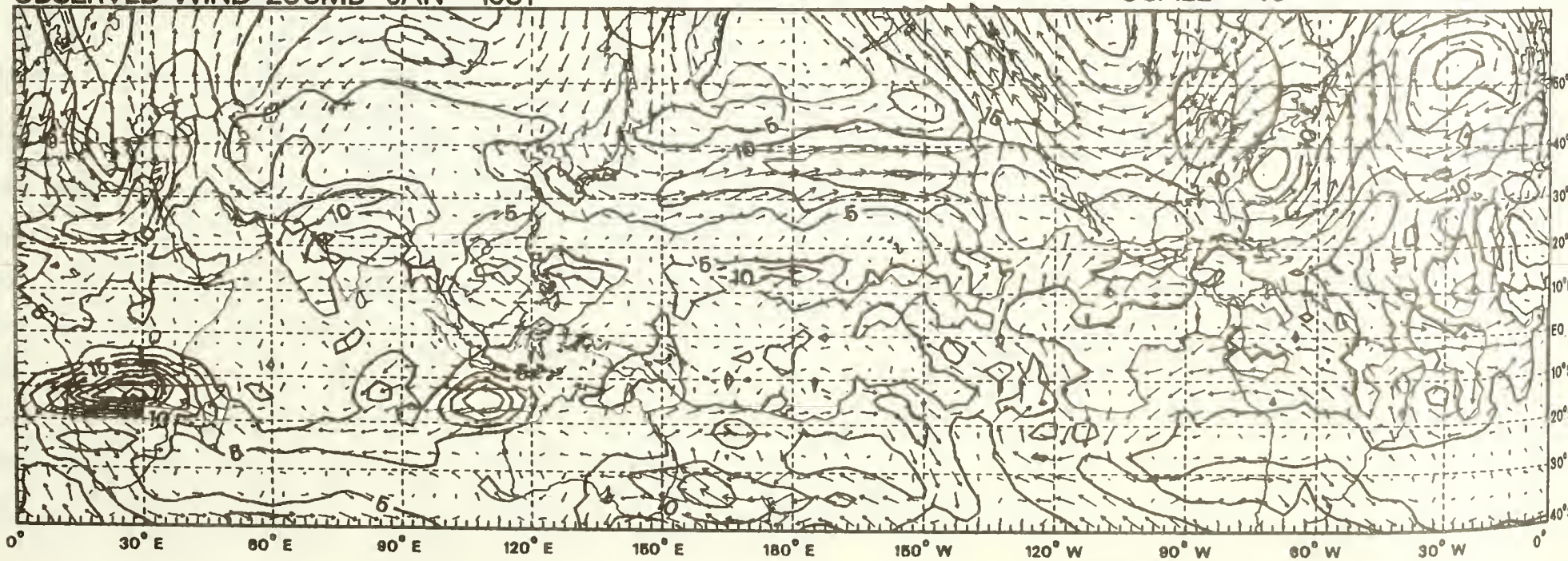
VELOCITY POTENTIAL 200MB DEC 1980



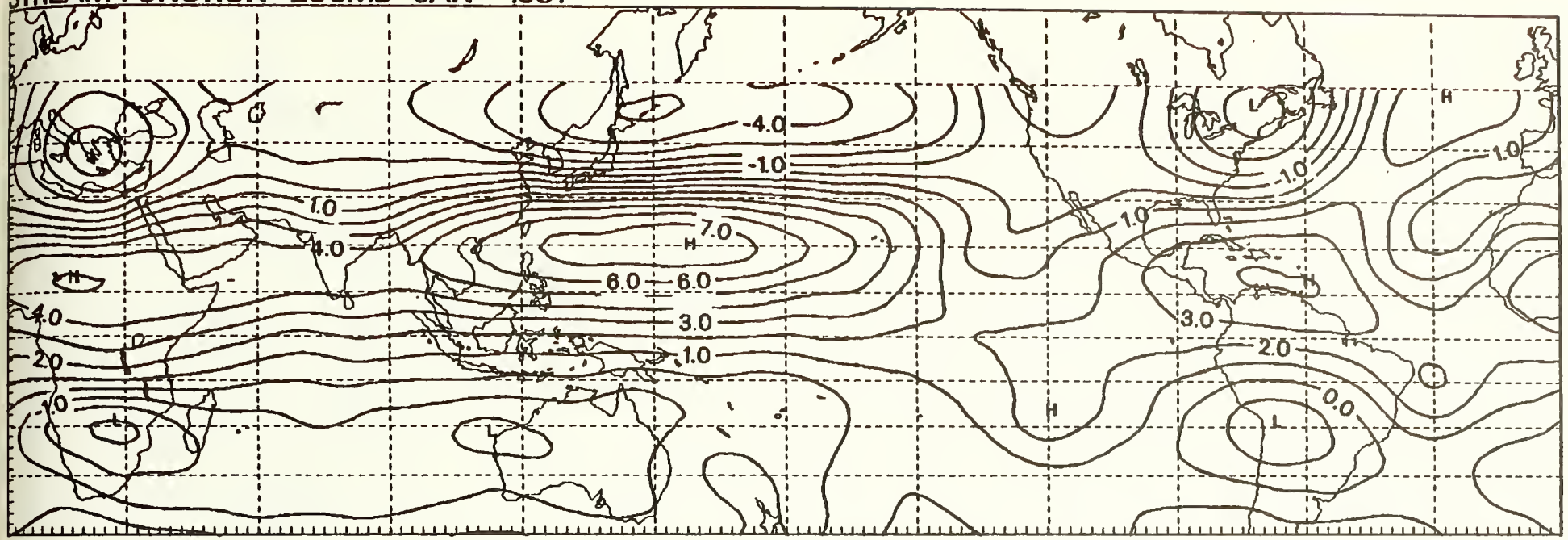
OBSERVED WIND 200MB JAN 1981 SCALE = 20



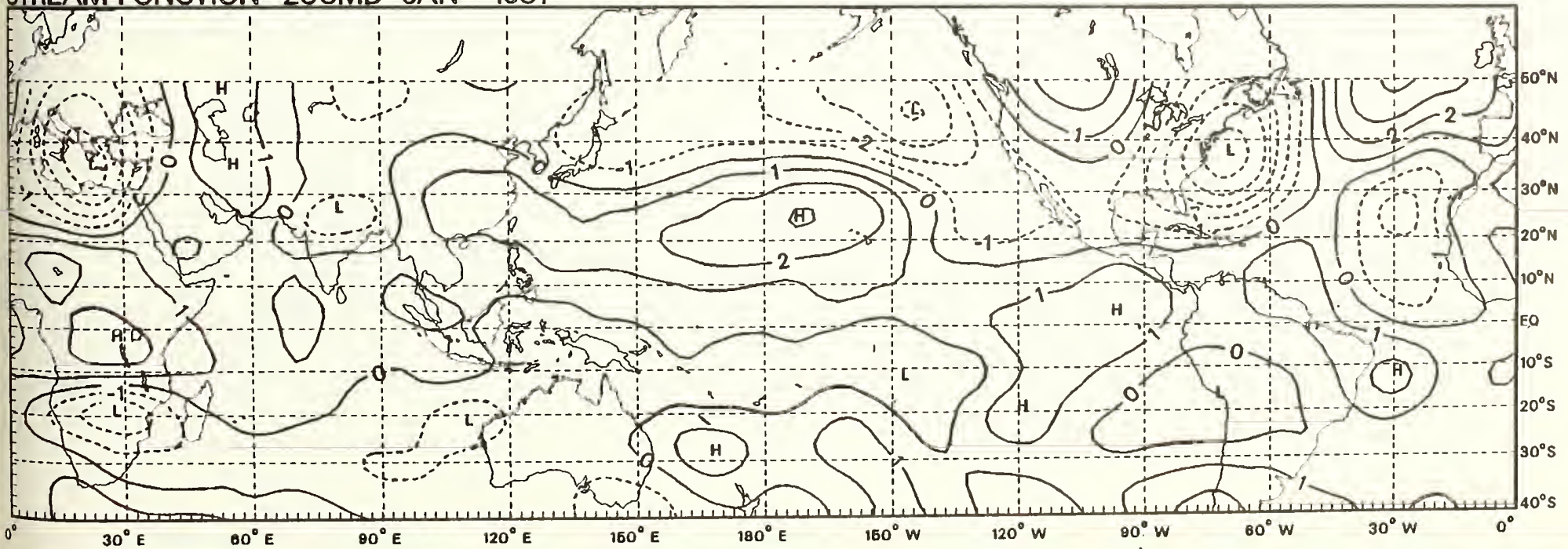
OBSERVED WIND 200MB JAN 1981 SCALE = 10



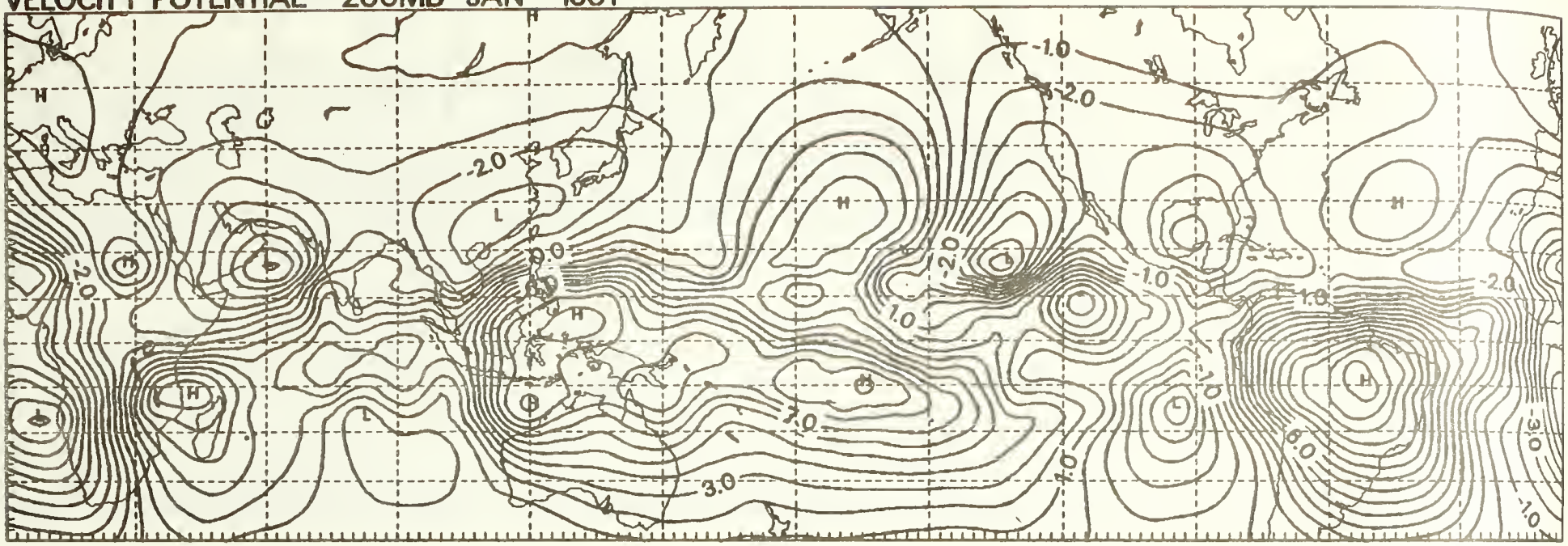
STREAM FUNCTION 200MB JAN 1981



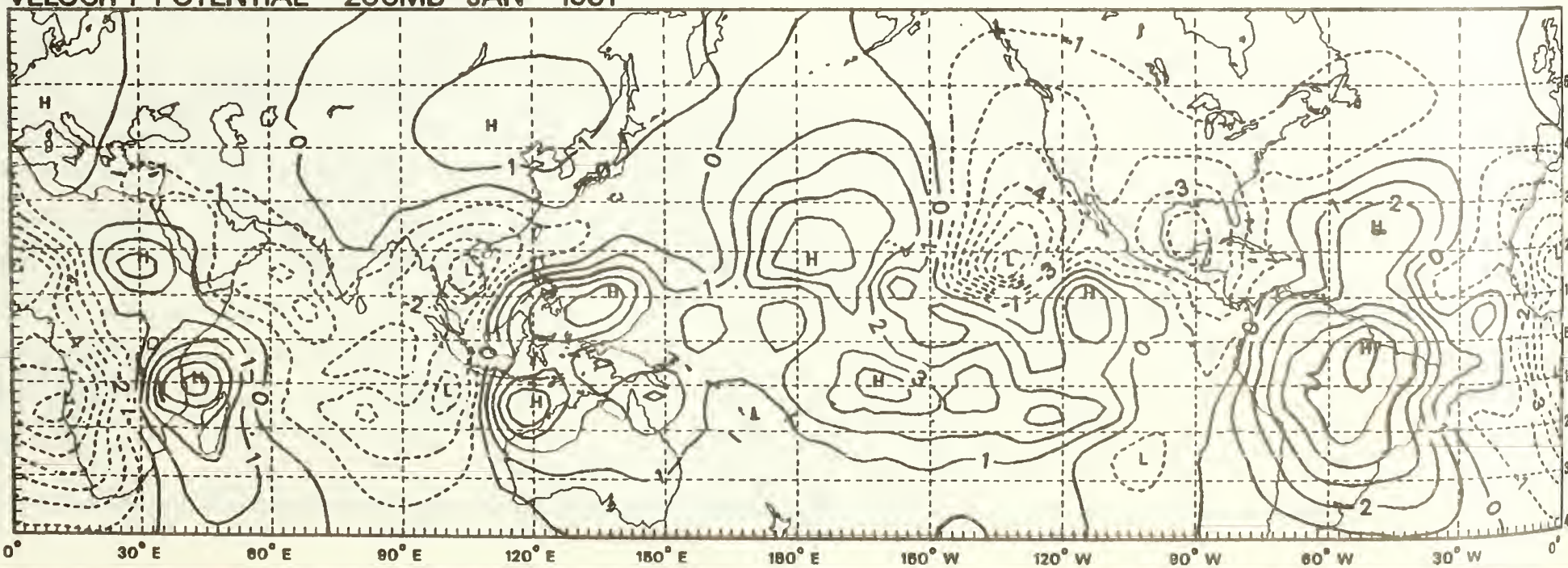
STREAM FUNCTION 200MB JAN 1981



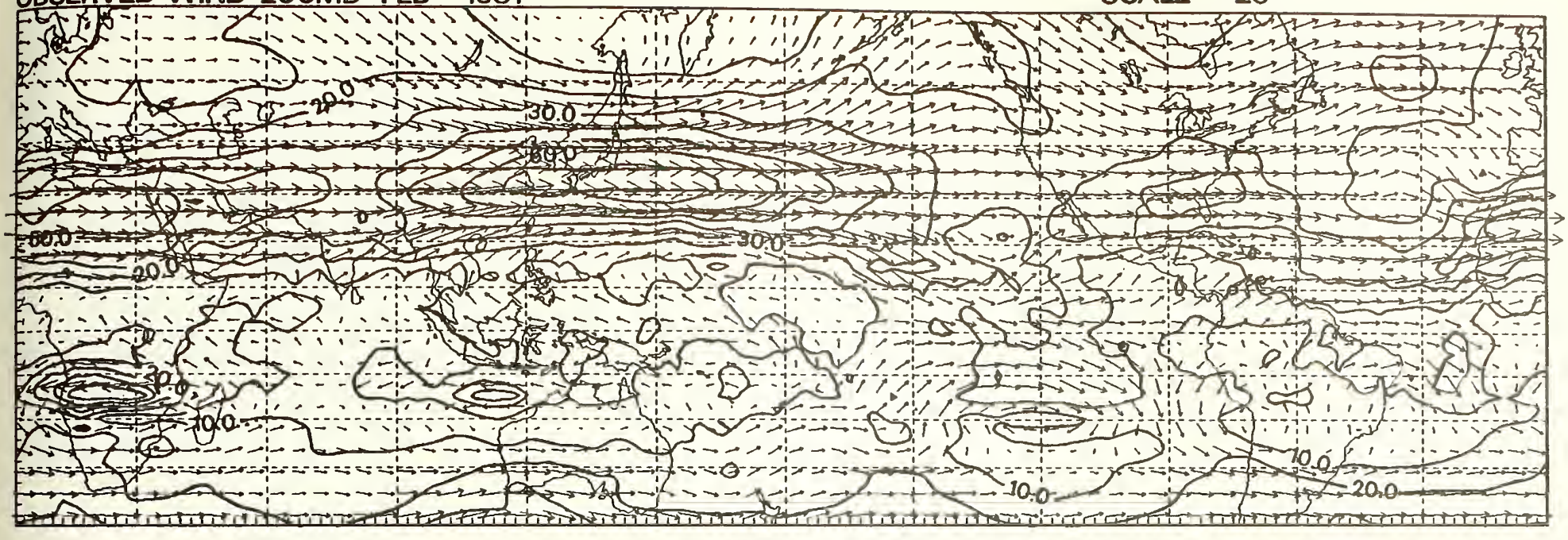
VELOCITY POTENTIAL 200MB JAN 1981



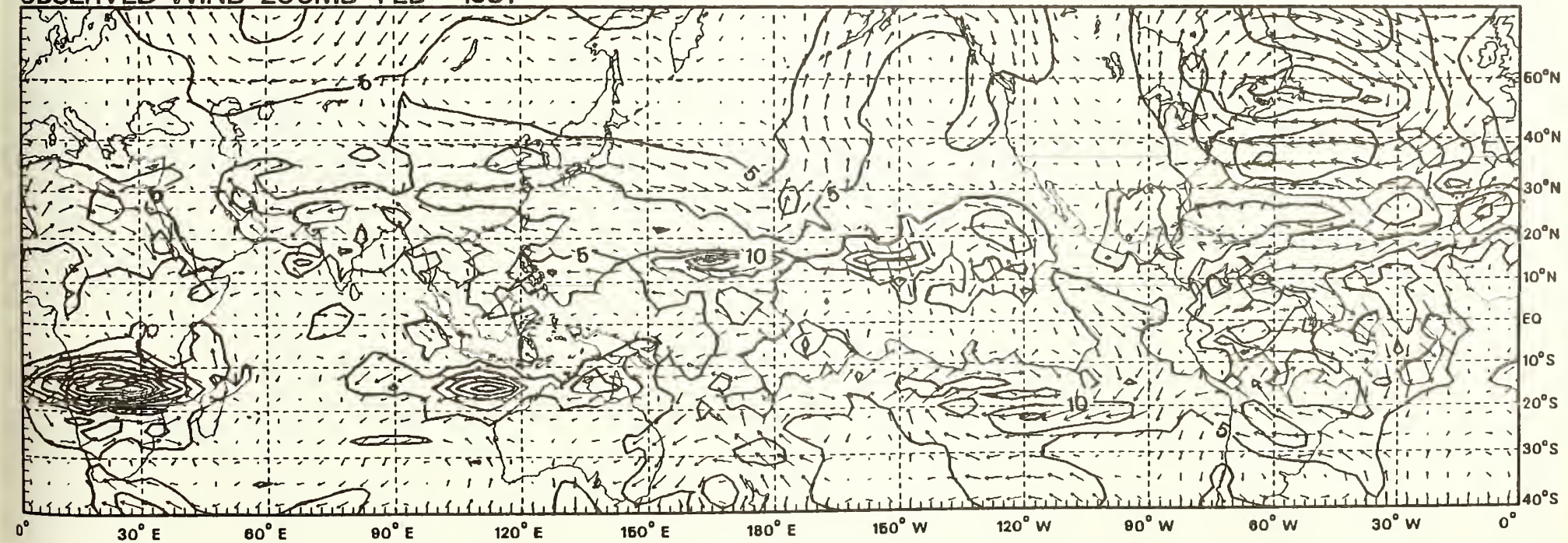
VELOCITY POTENTIAL 200MB JAN 1981



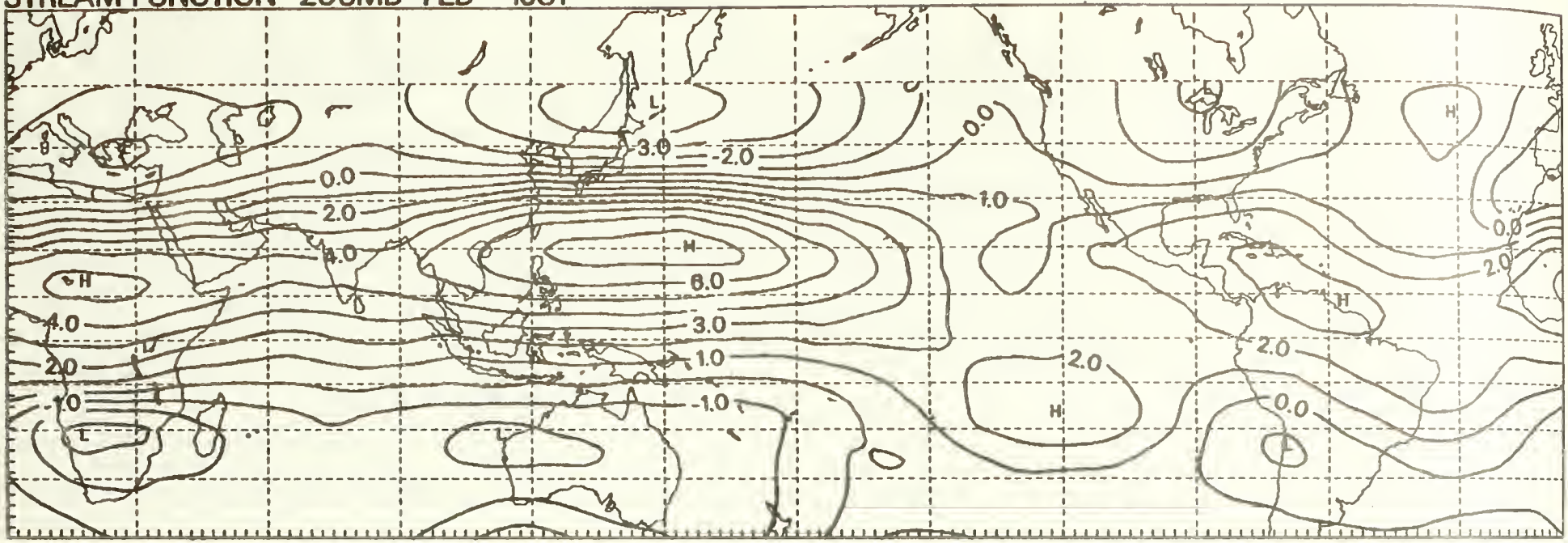
OBSERVED WIND 200MB FEB 1981 SCALE = 20



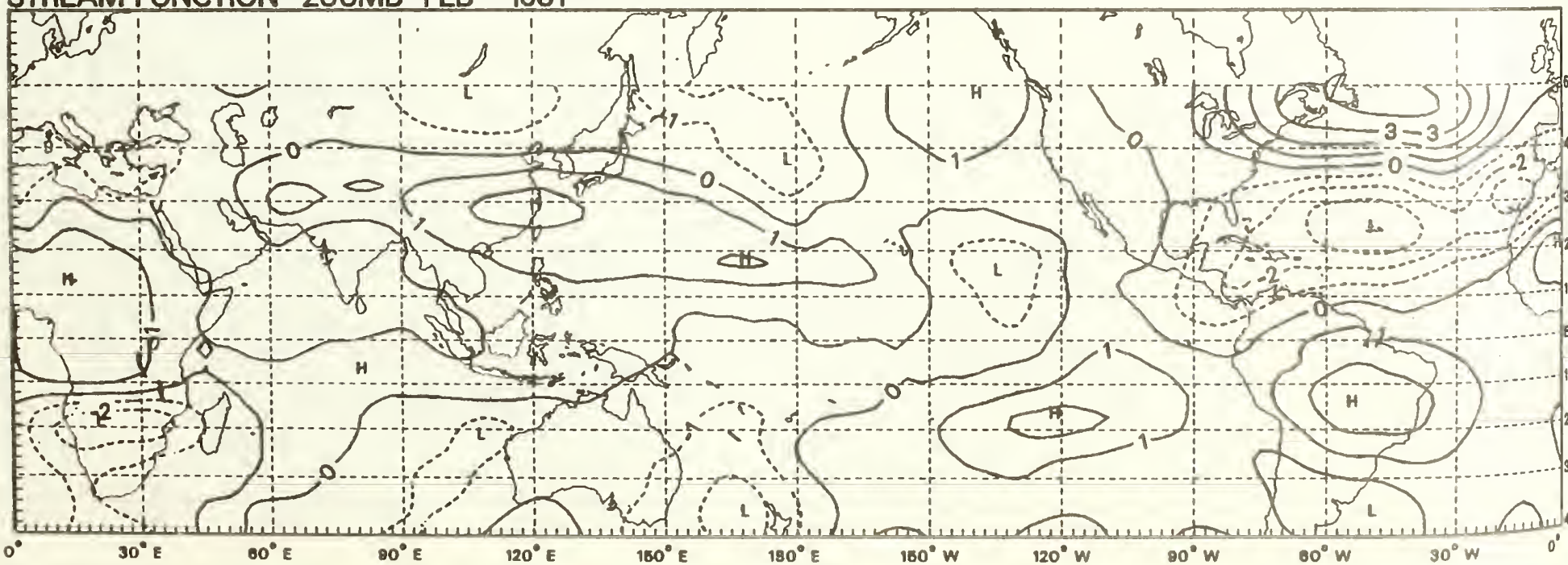
OBSERVED WIND 200MB FEB 1981 SCALE = 10



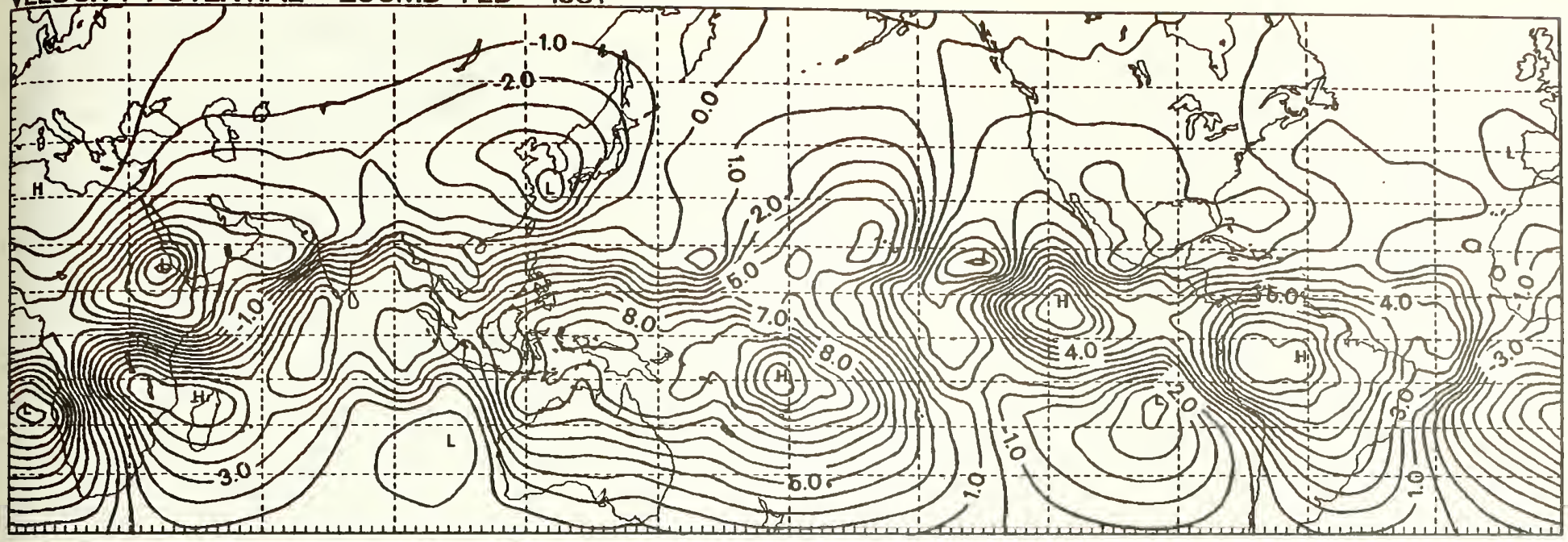
STREAM FUNCTION 200MB FEB 1981



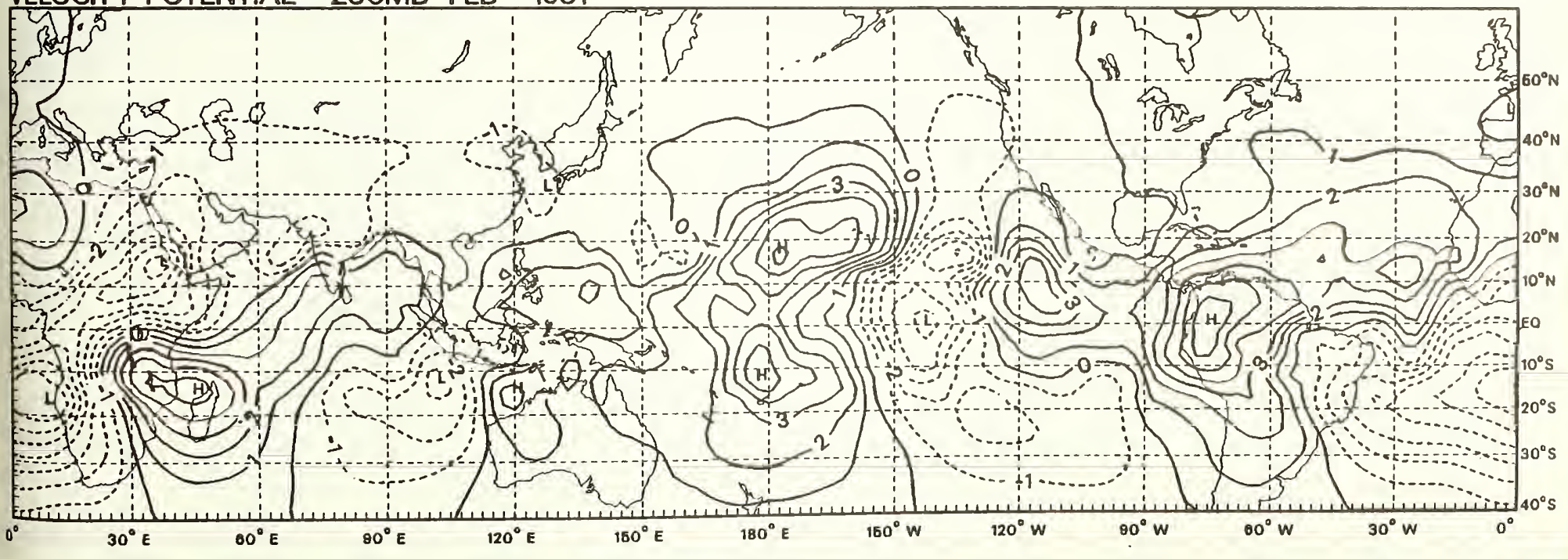
STREAM FUNCTION 200MB FEB 1981



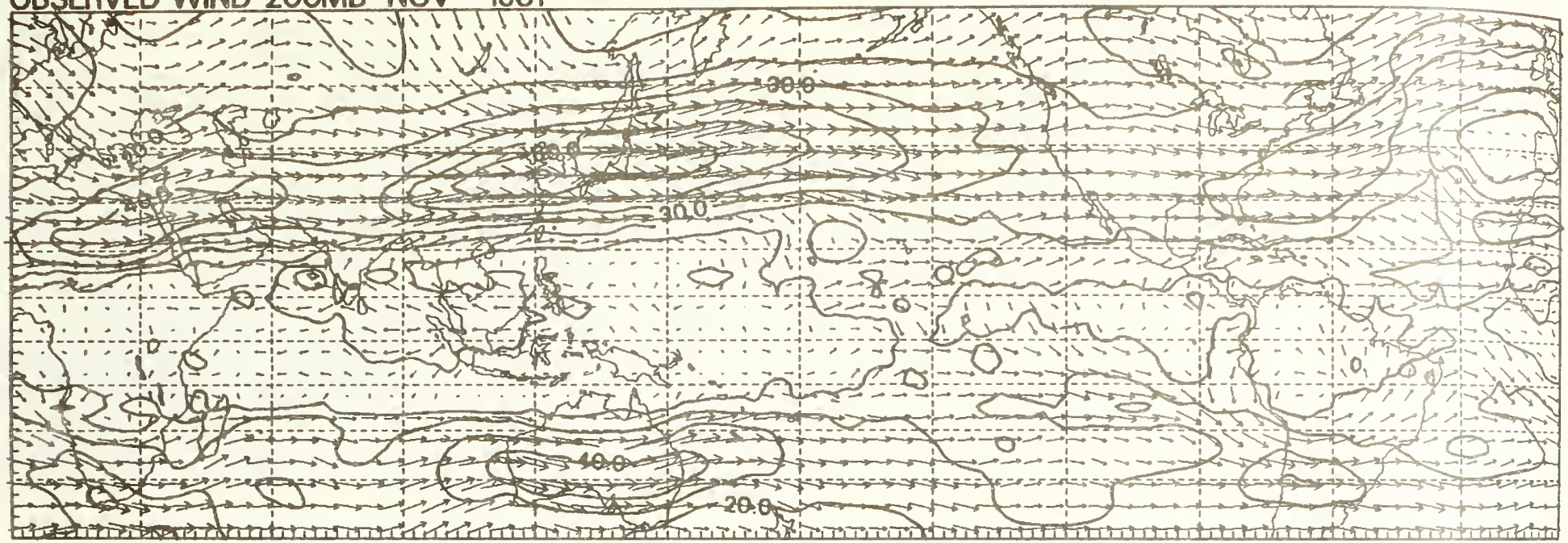
VELOCITY POTENTIAL 200MB FEB 1981



VELOCITY POTENTIAL 200MB FEB 1981



OBSERVED WIND 200MB NOV 1981 SCALE = 20



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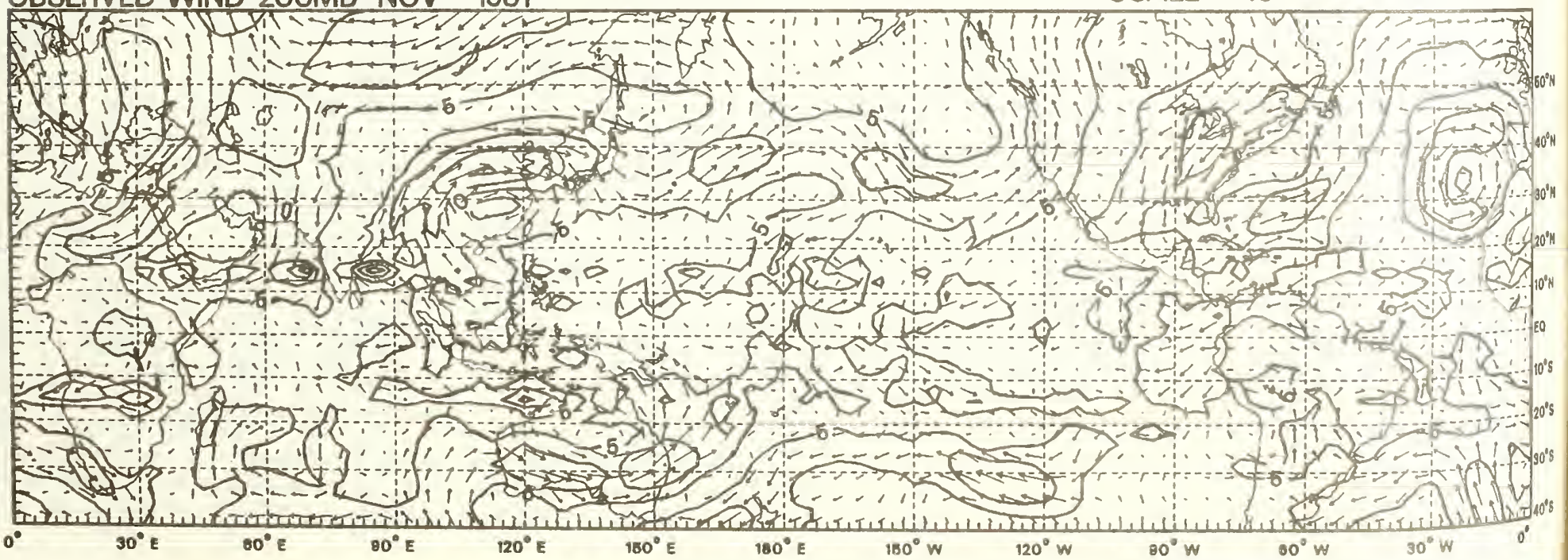

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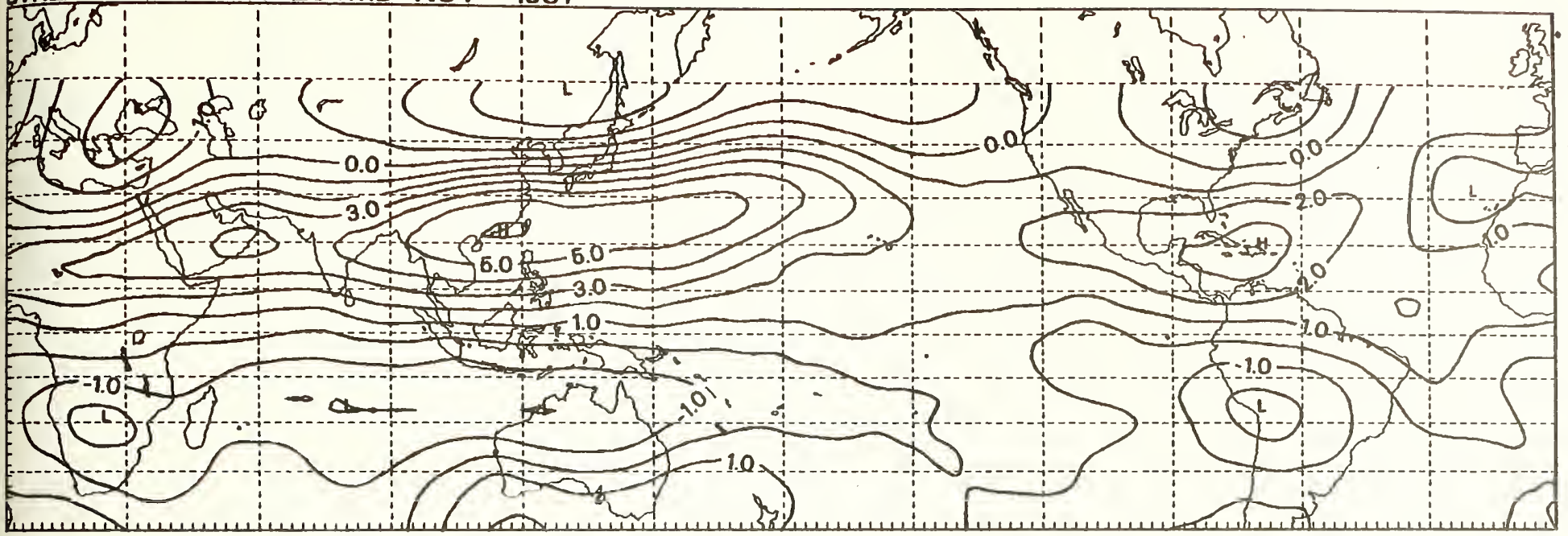

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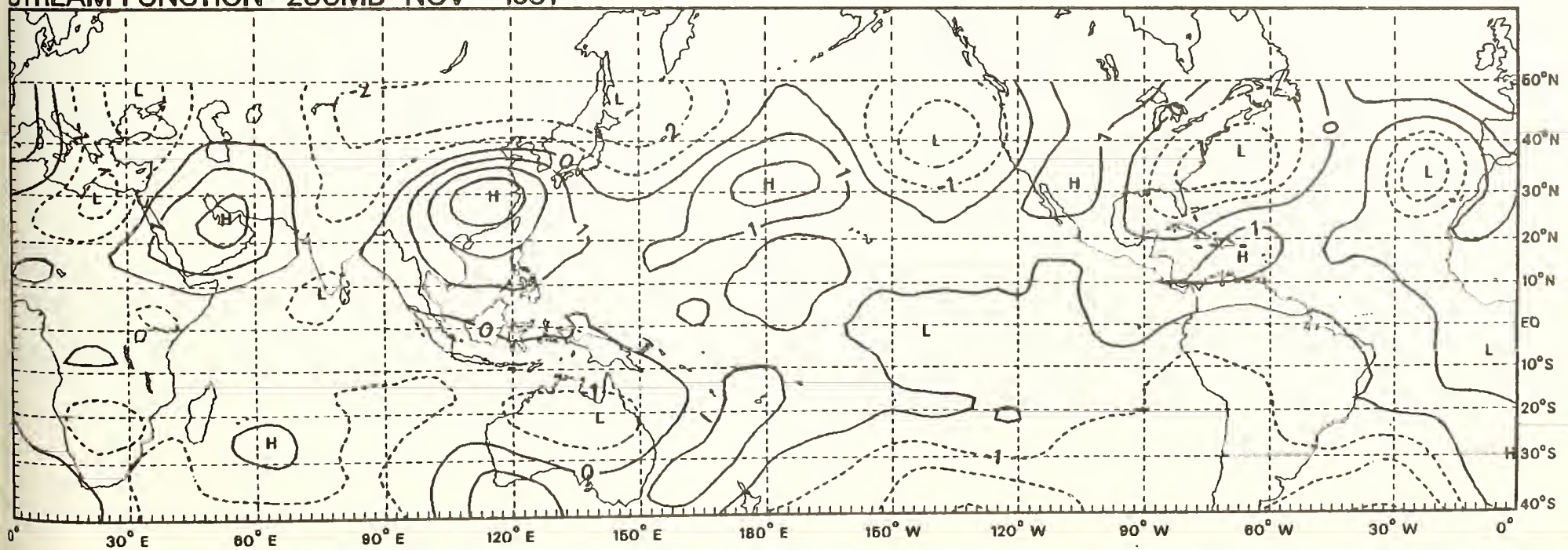

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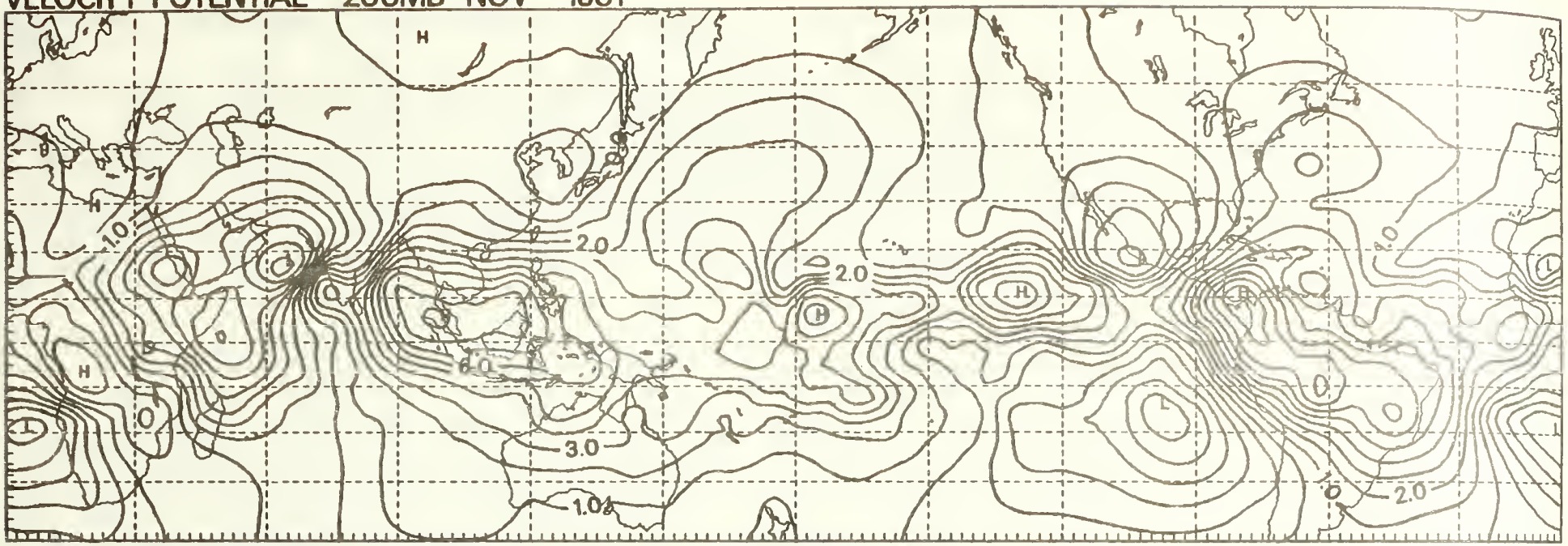

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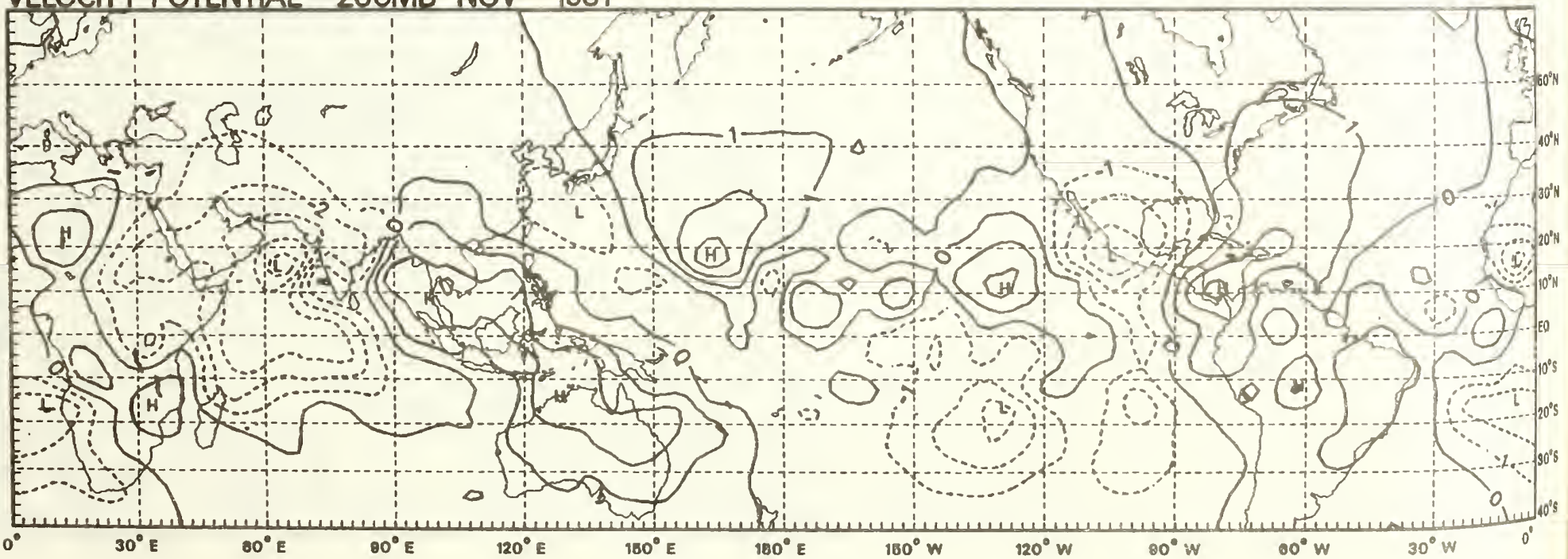

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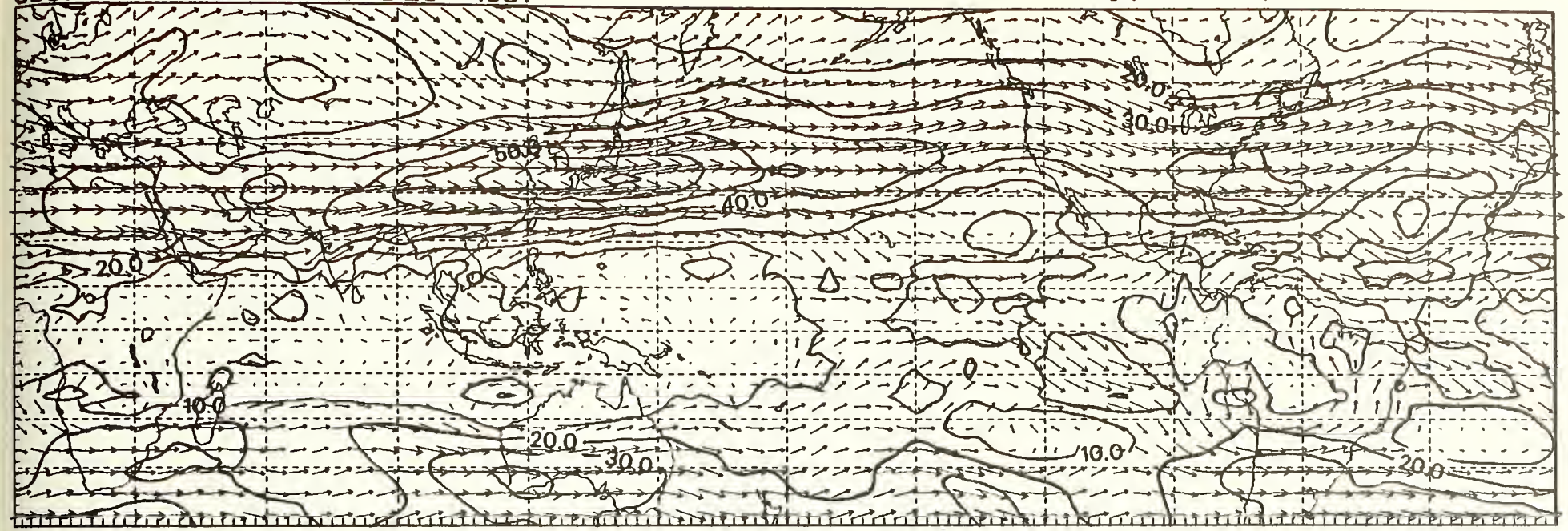

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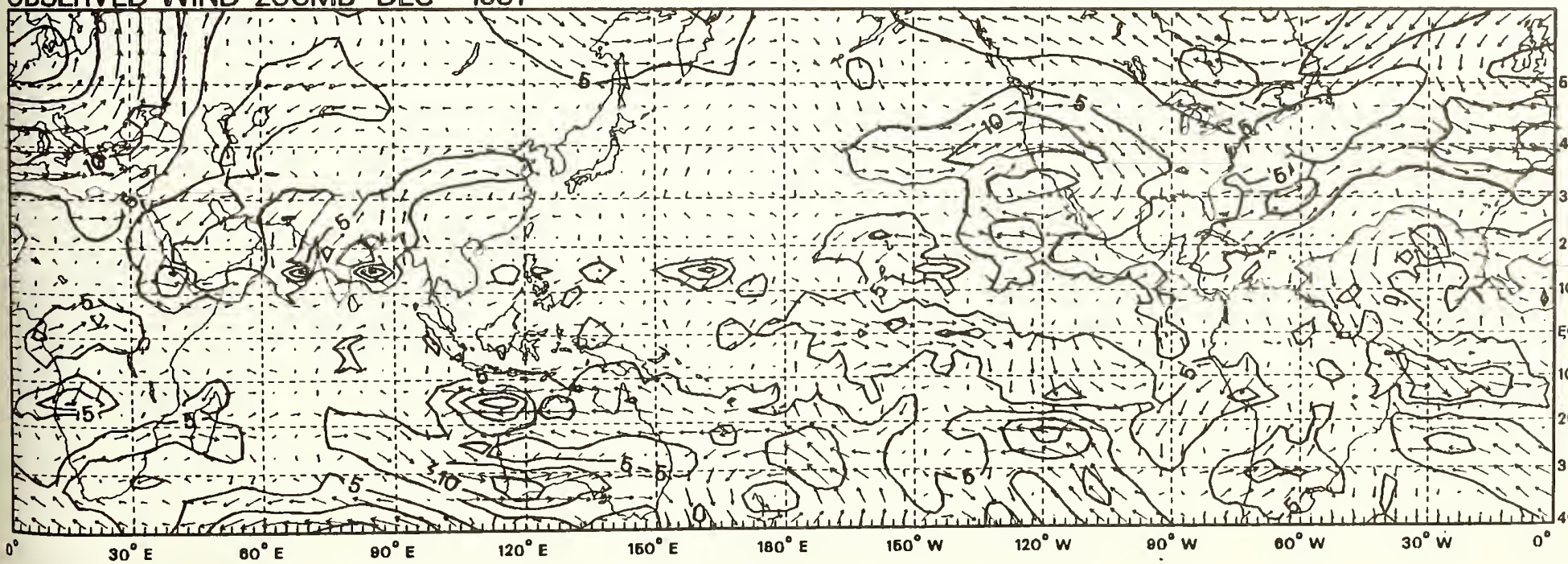
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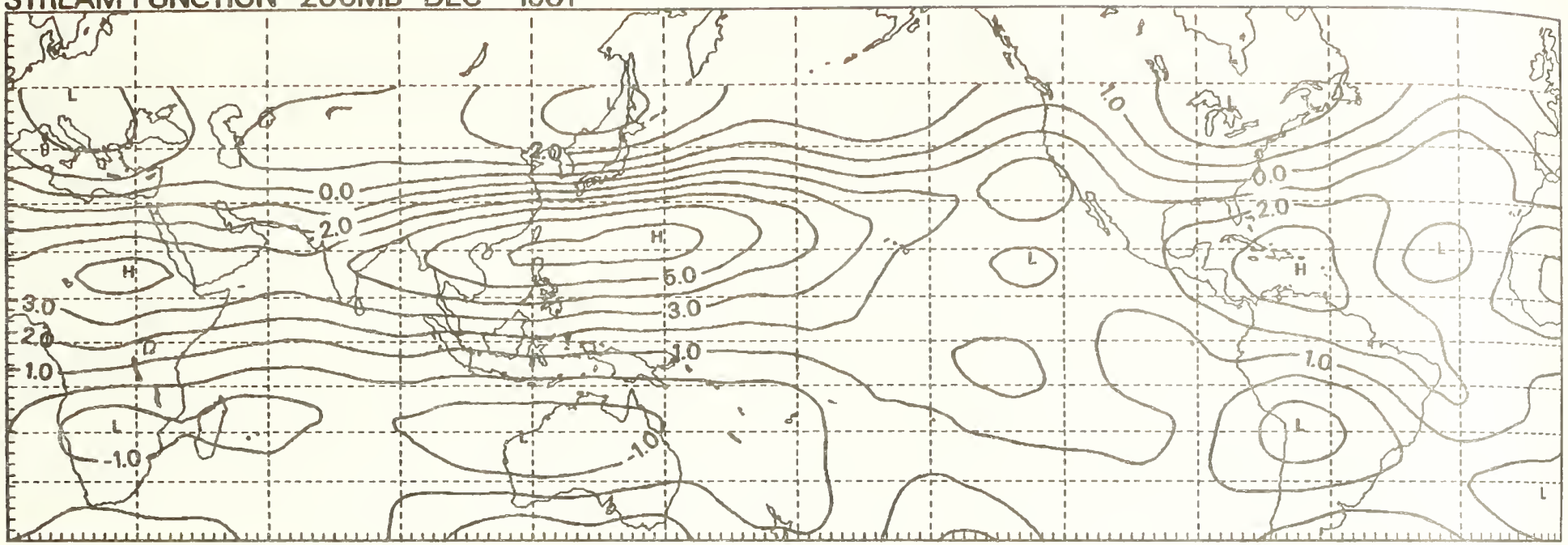

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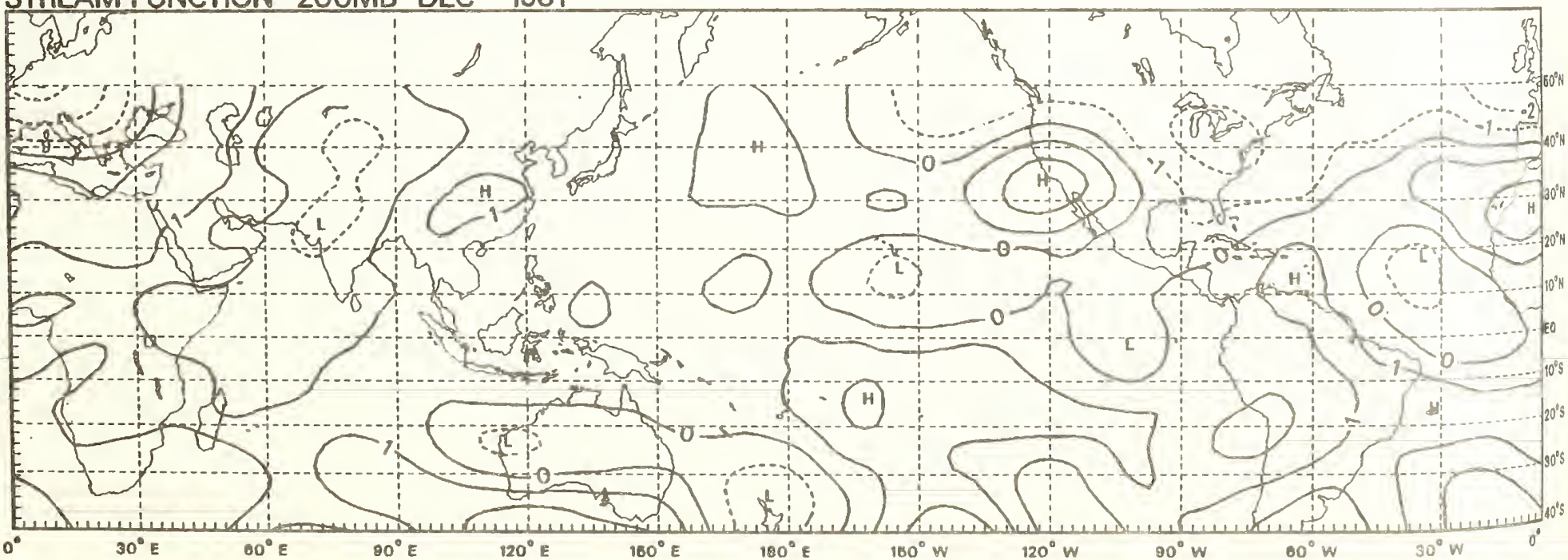

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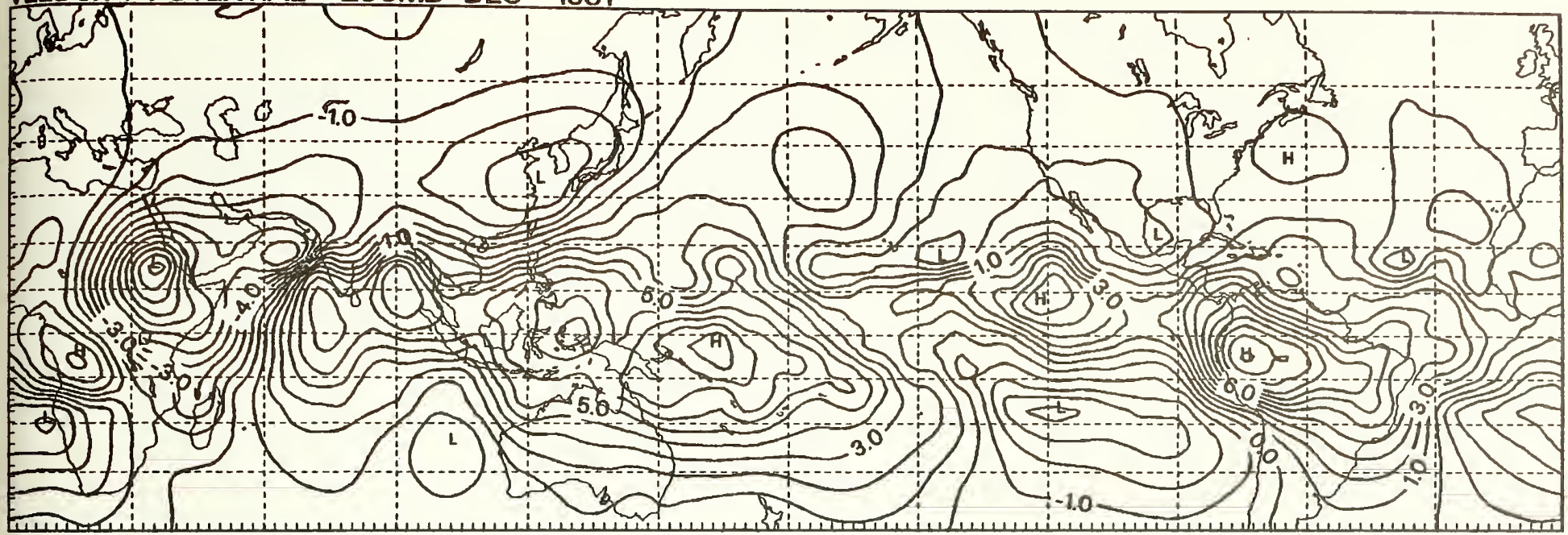

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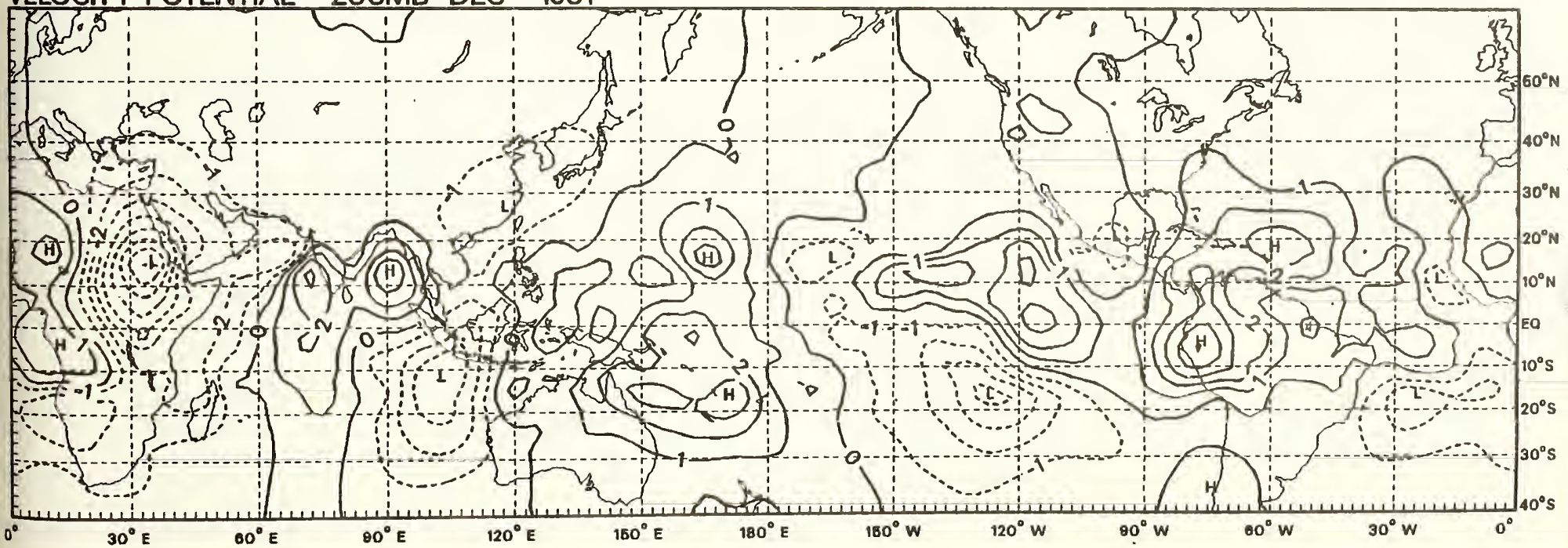

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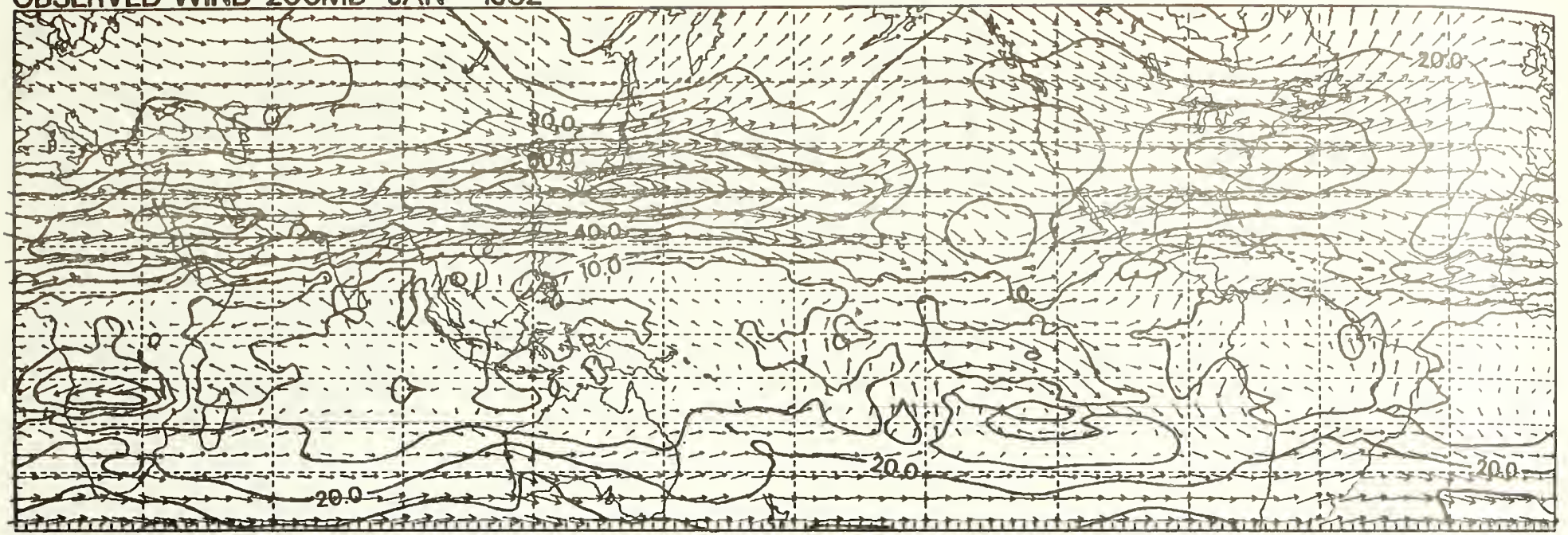

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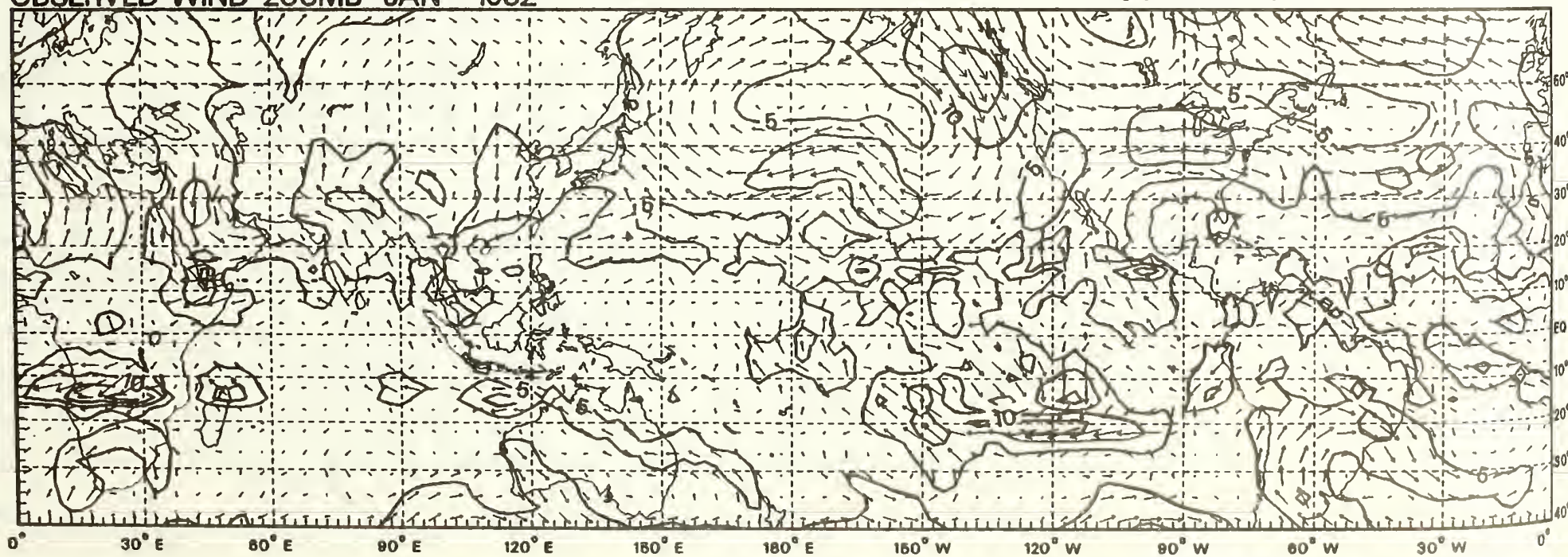

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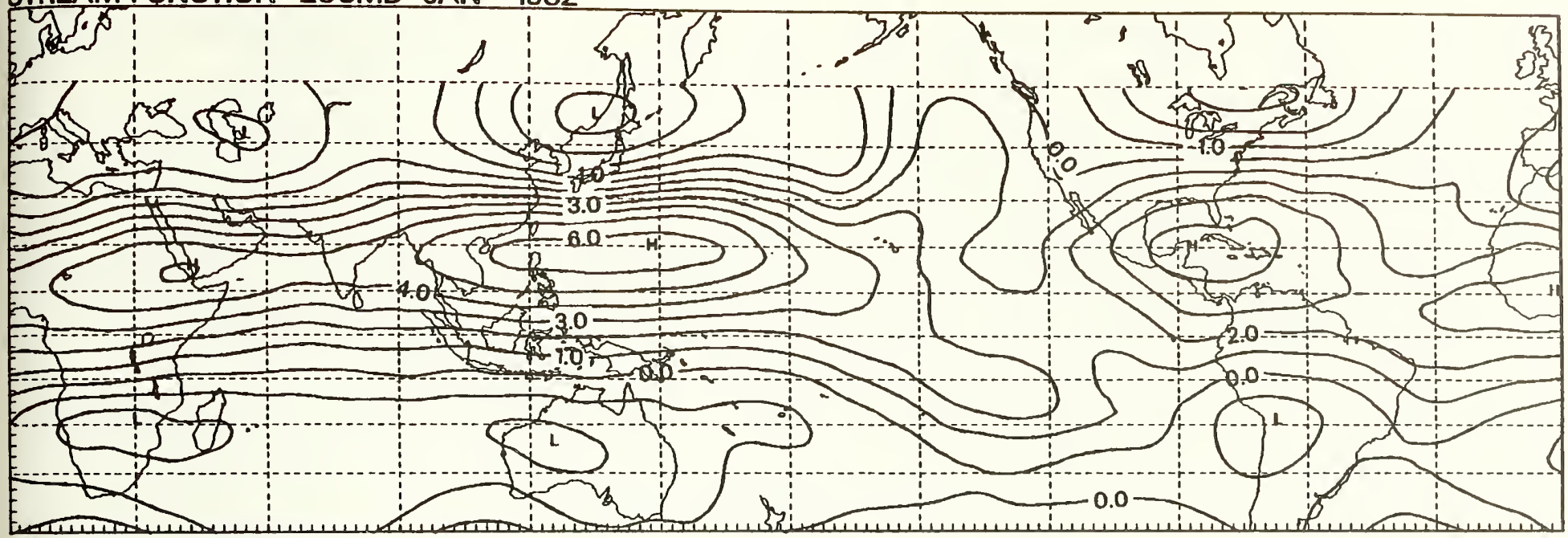

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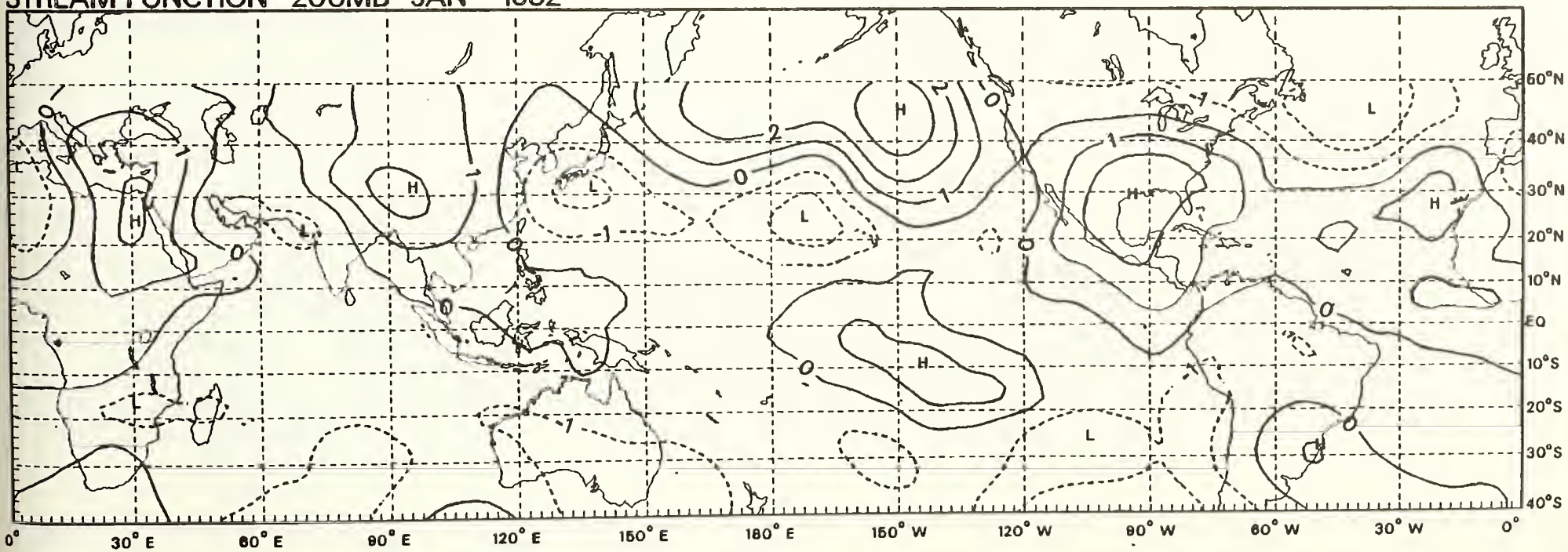

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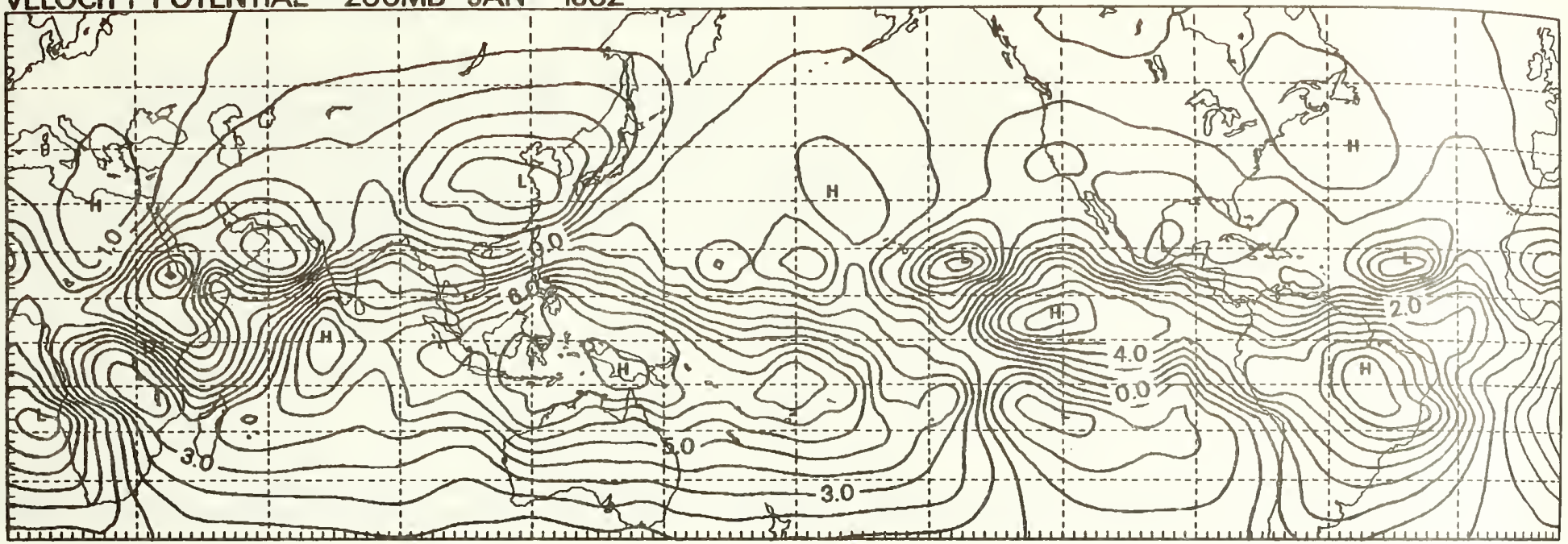

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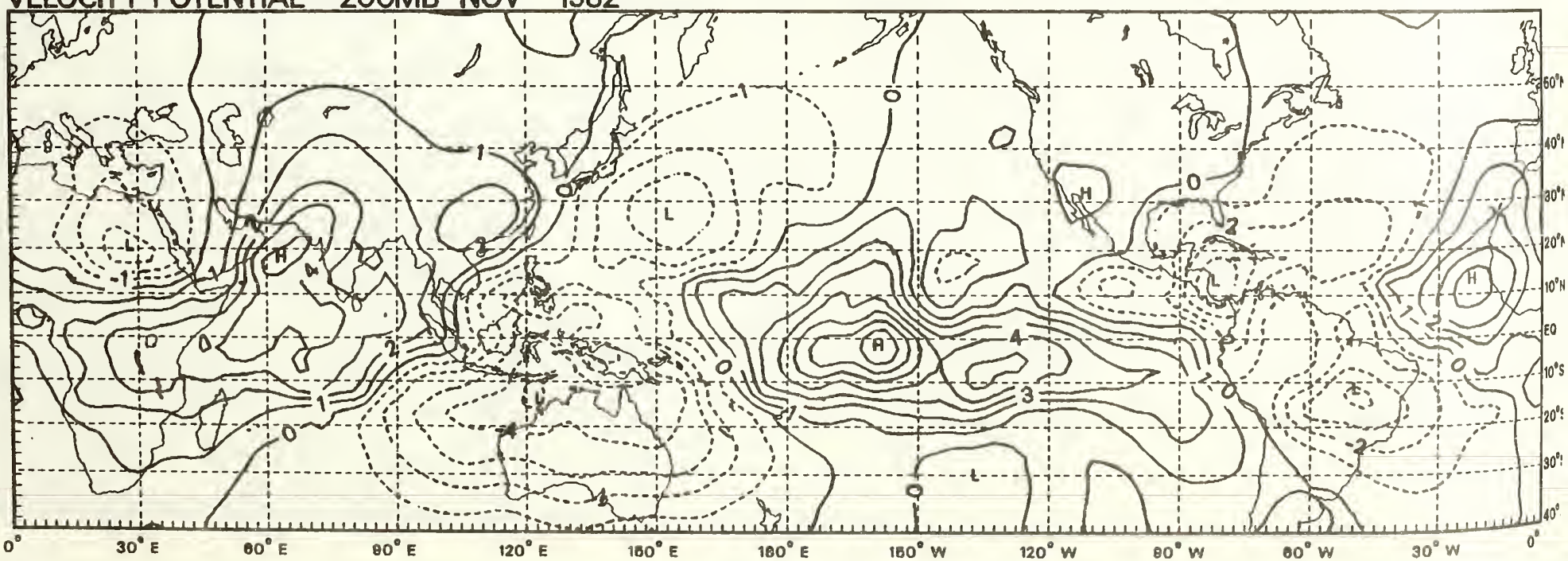

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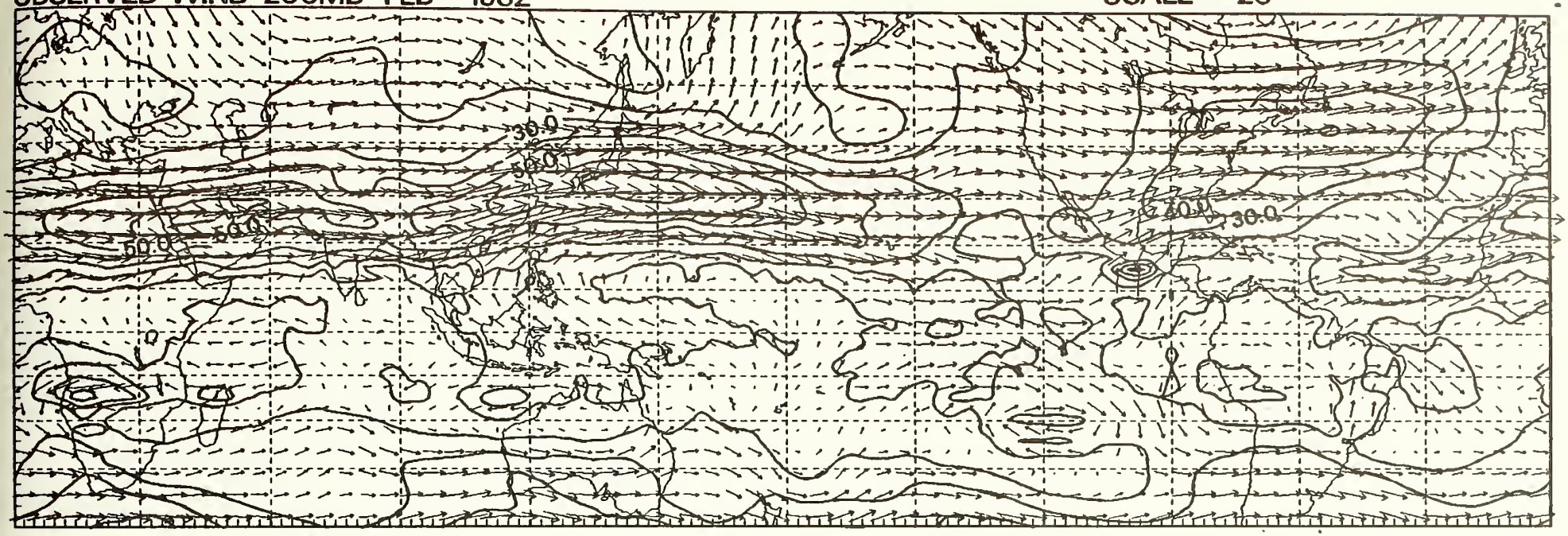

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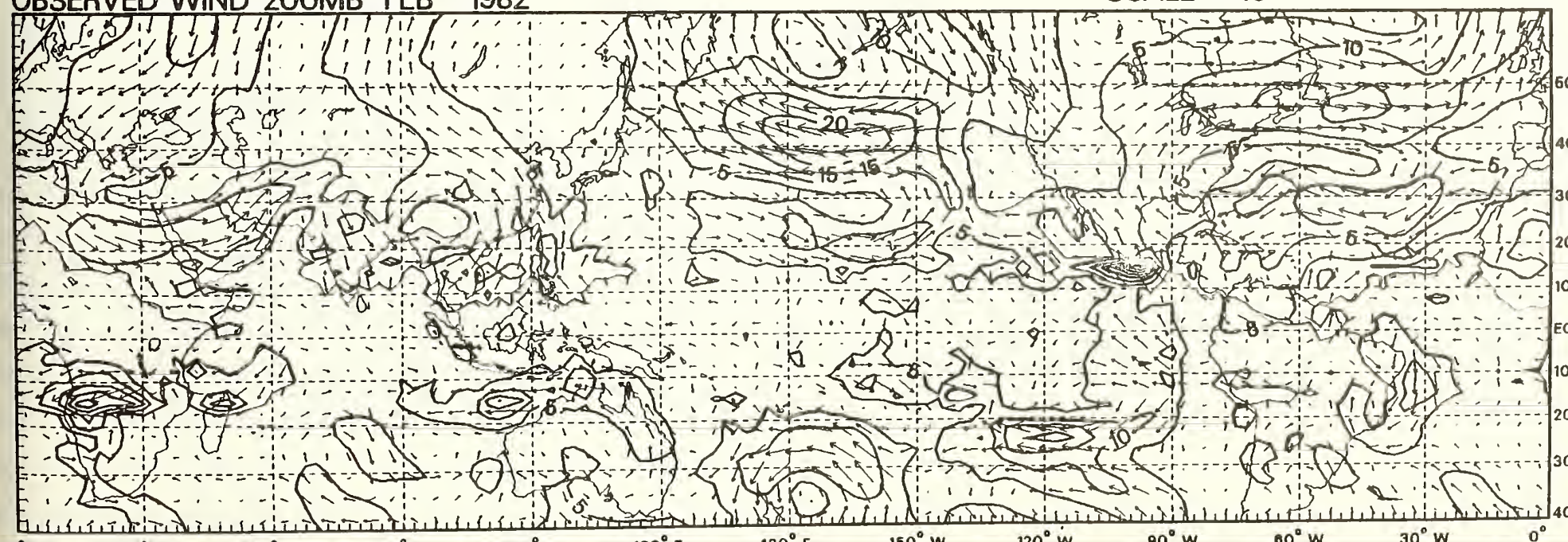

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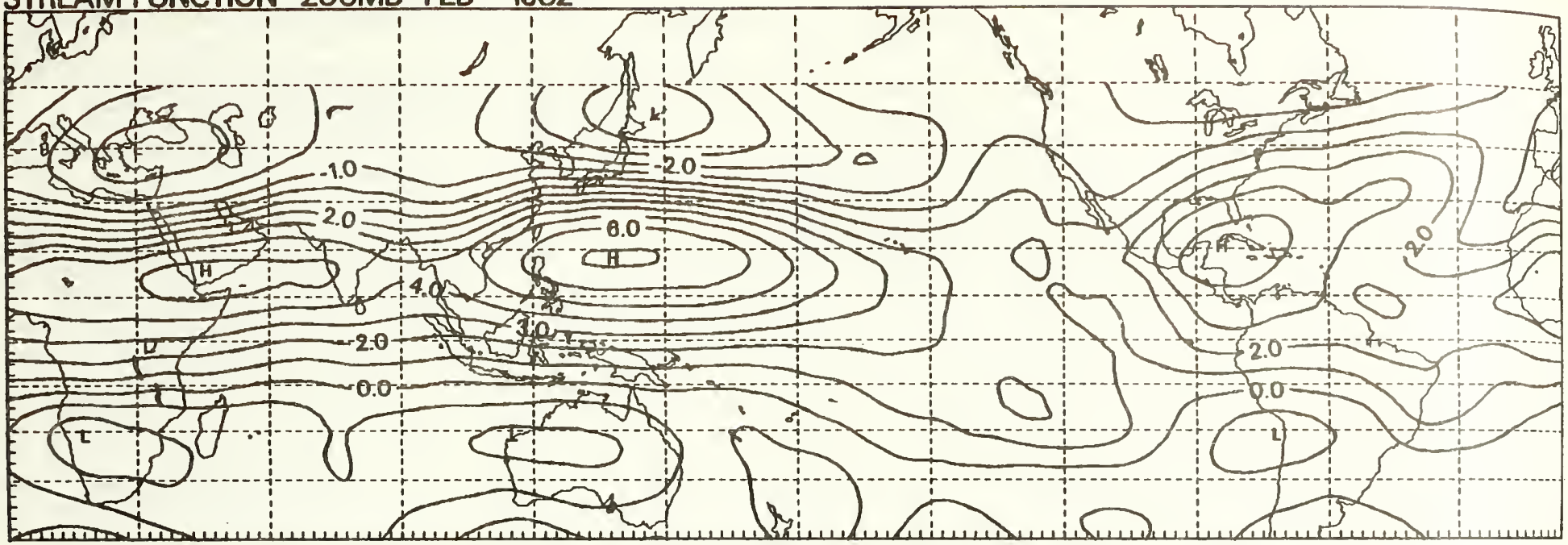

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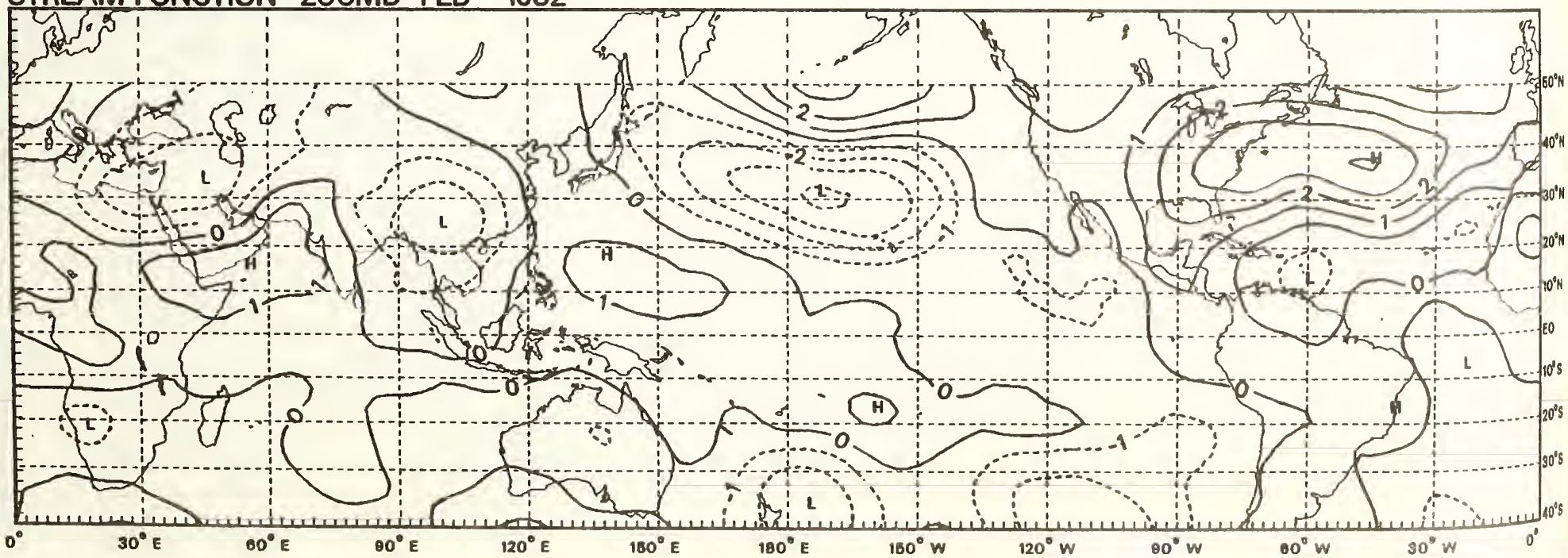

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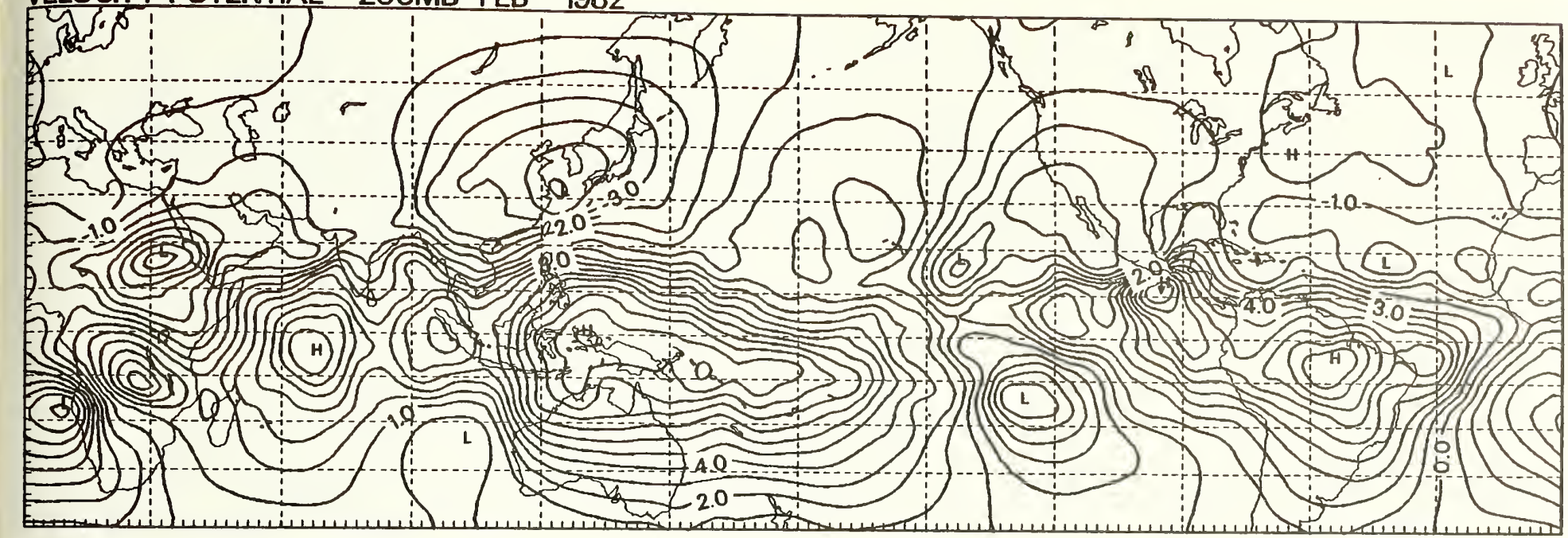

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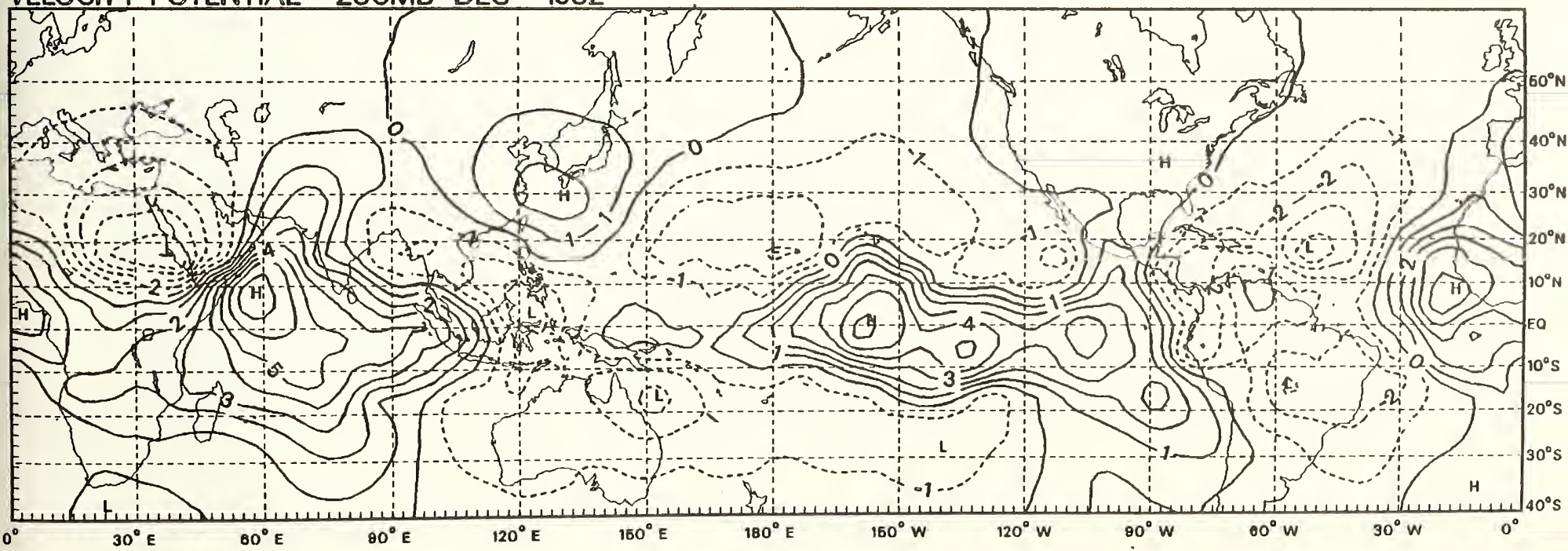

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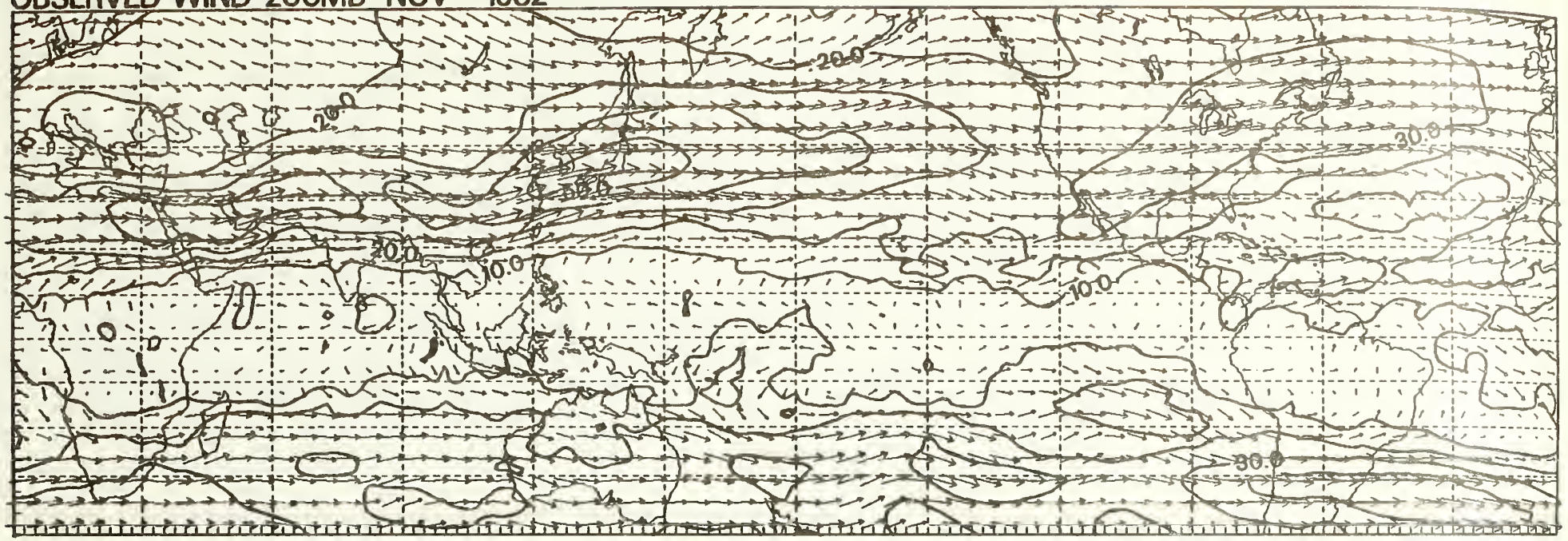

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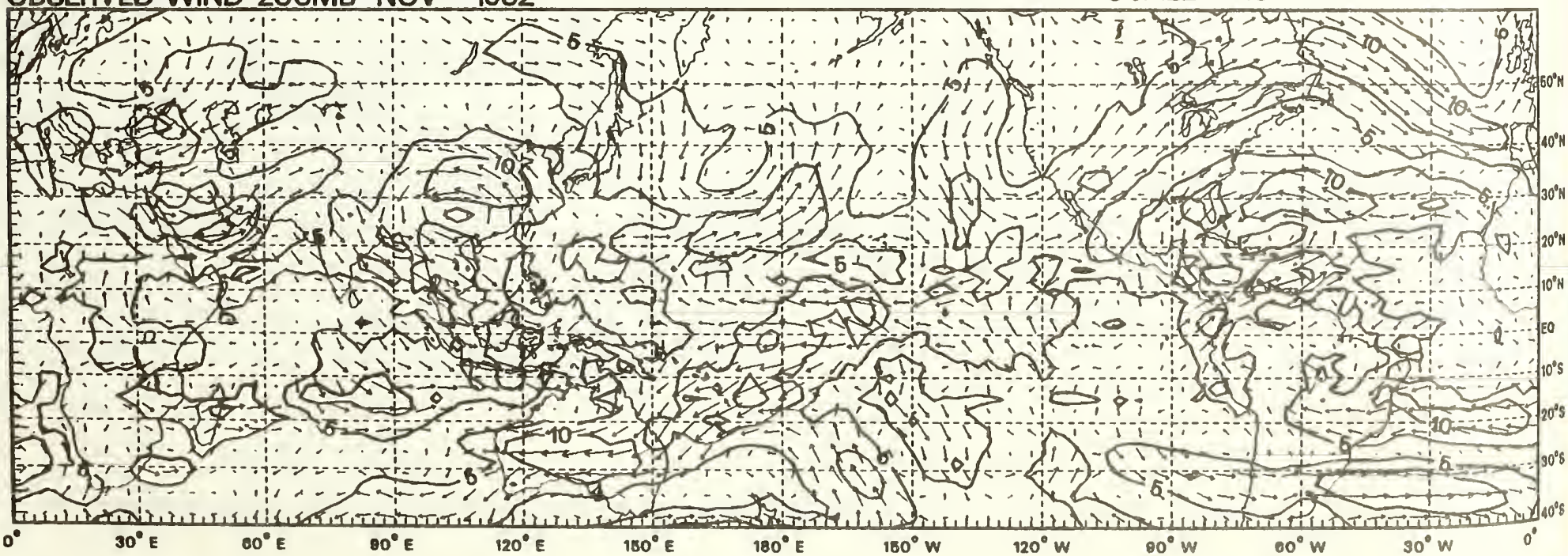

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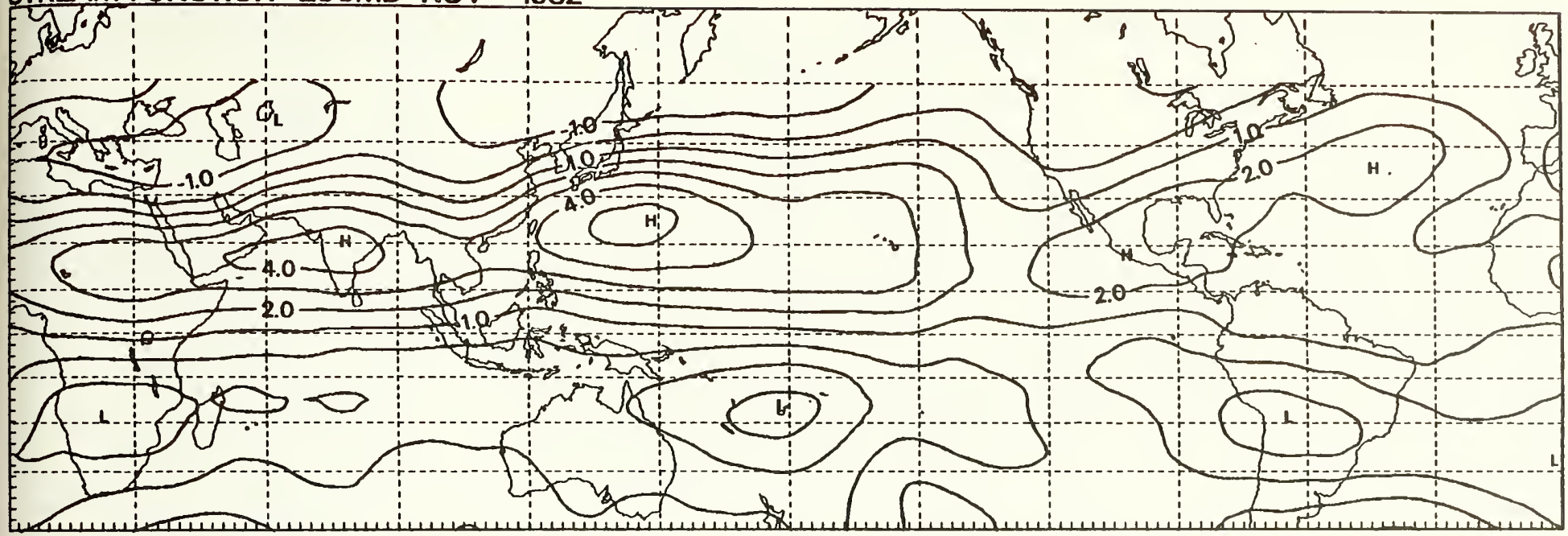

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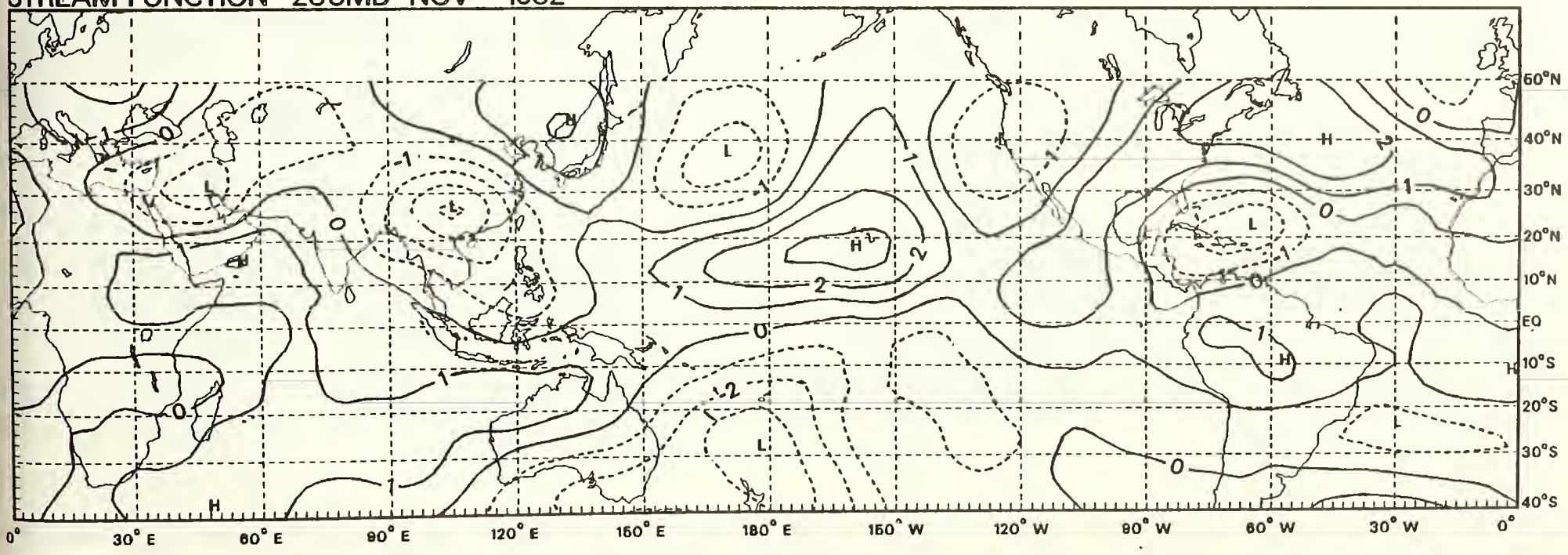

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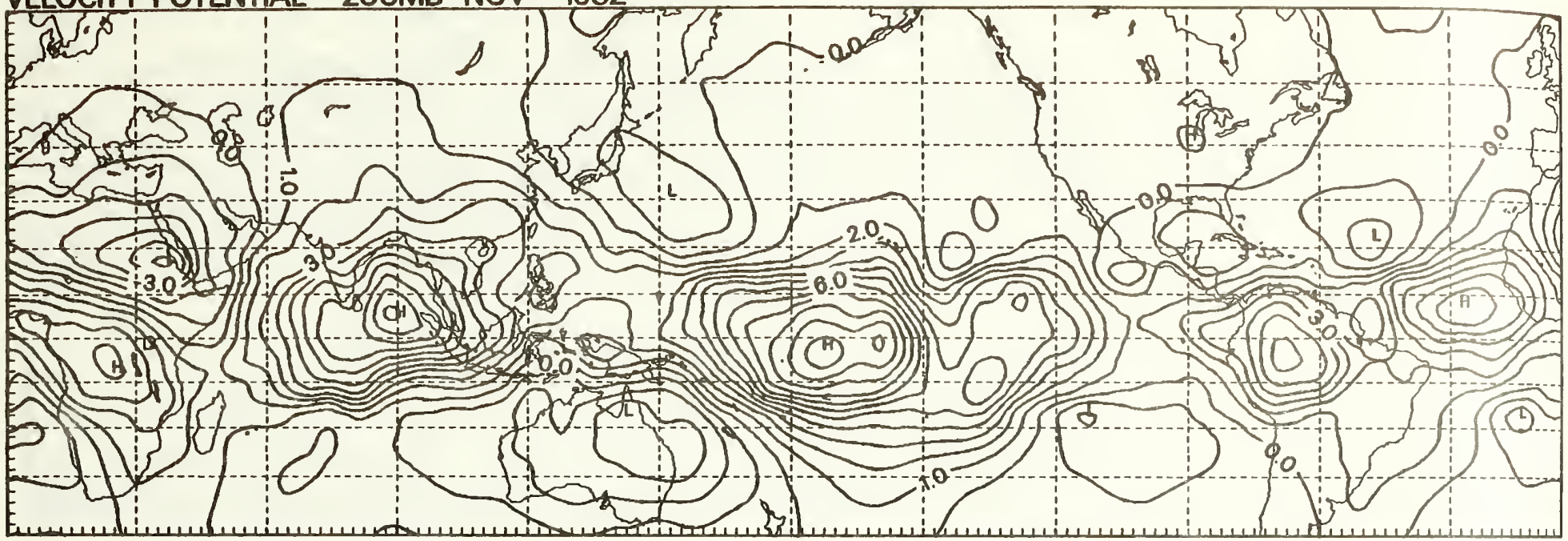

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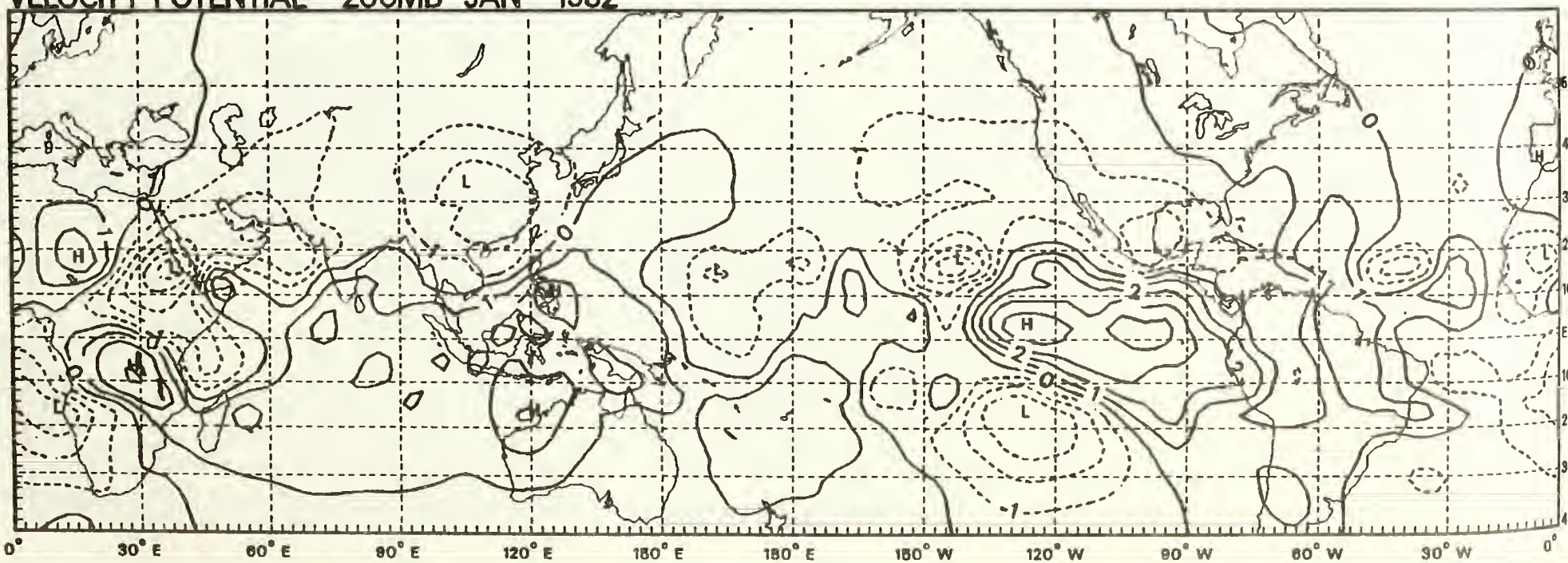

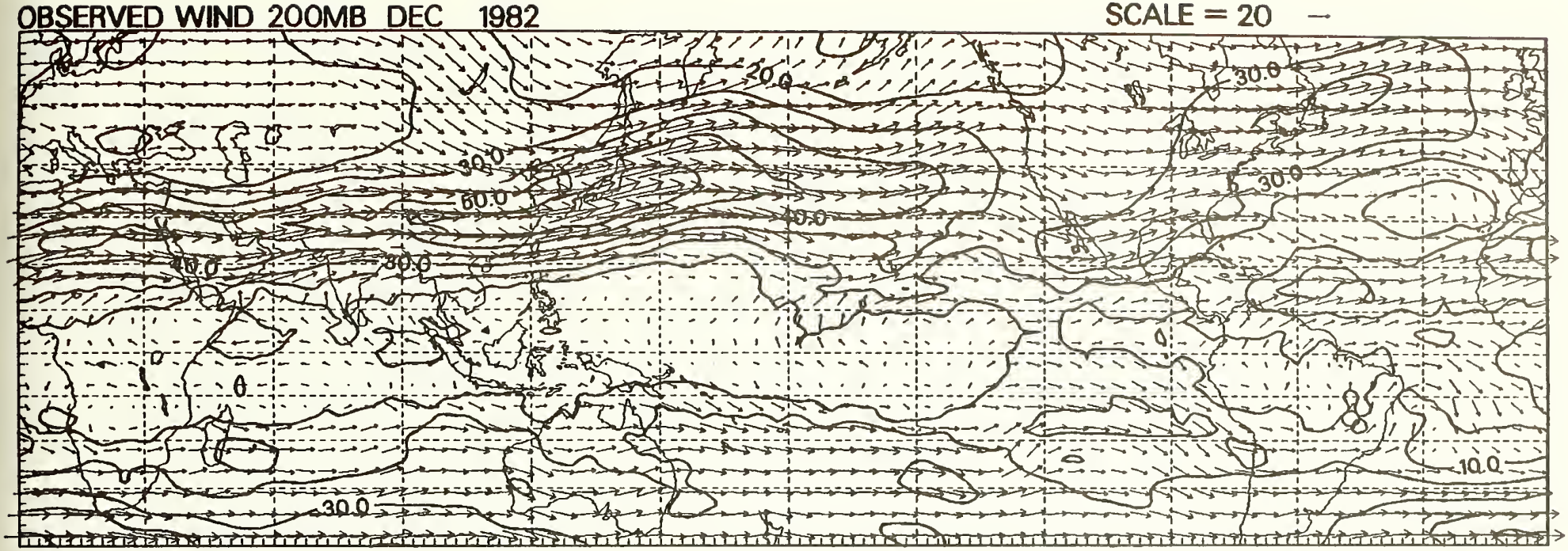
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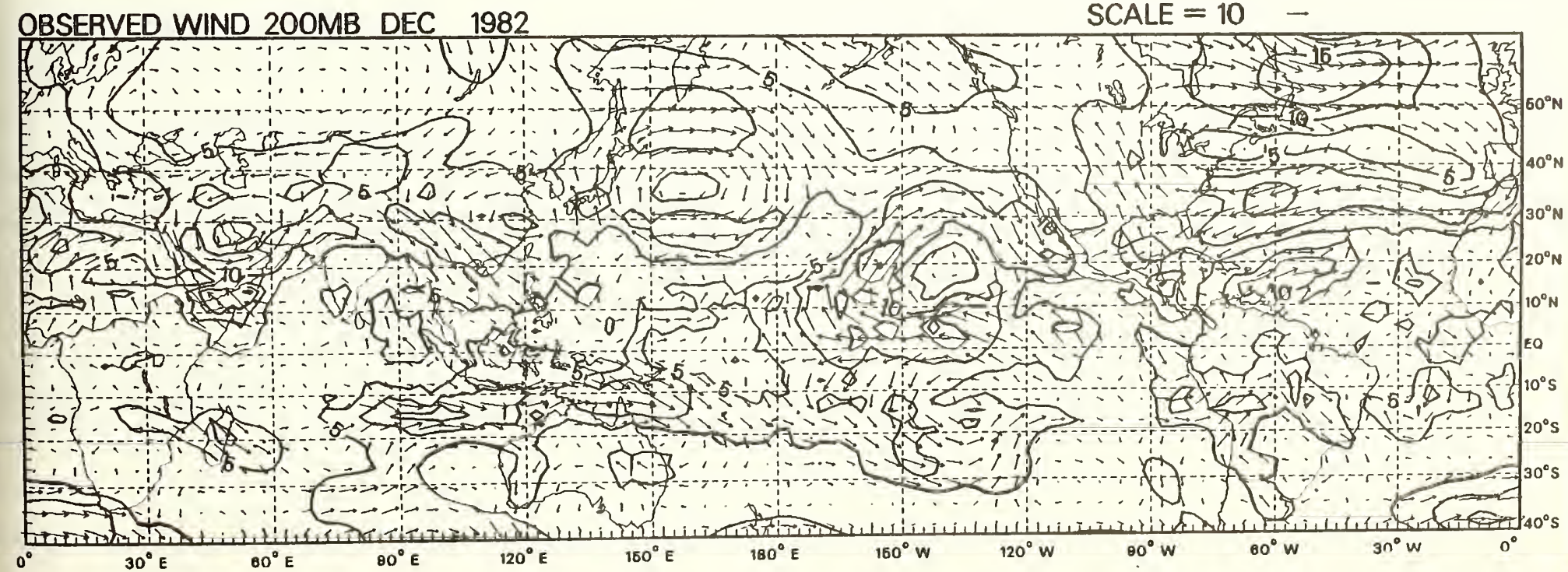
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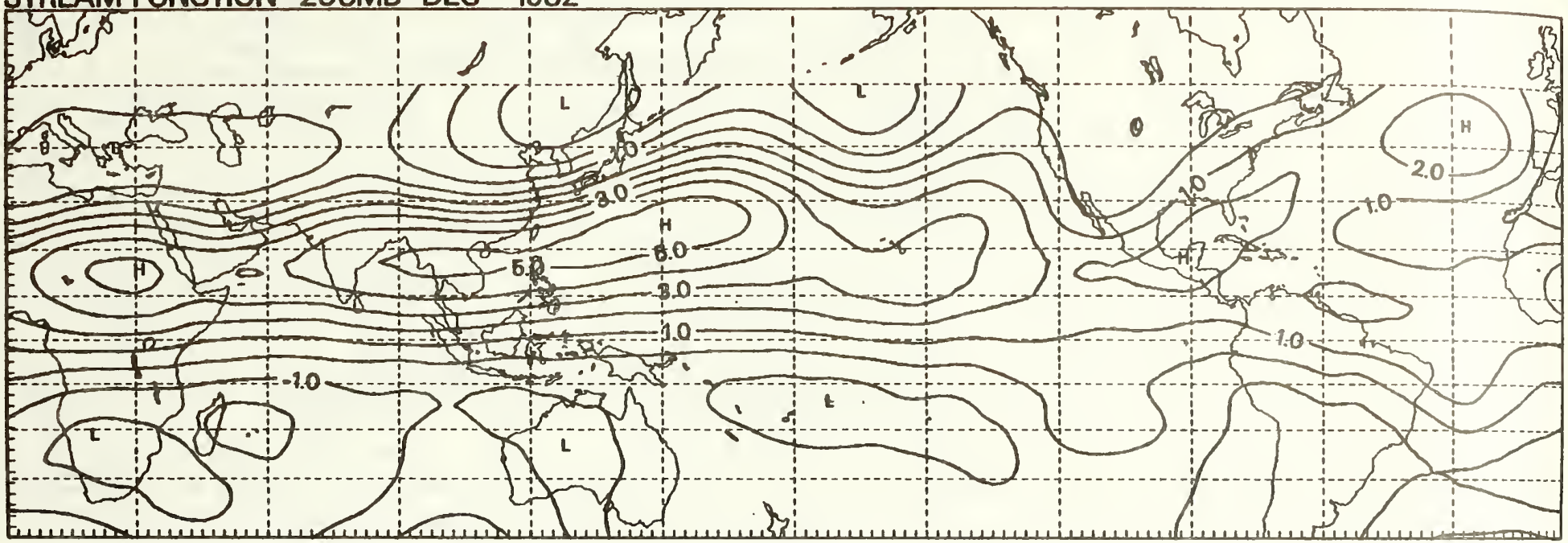

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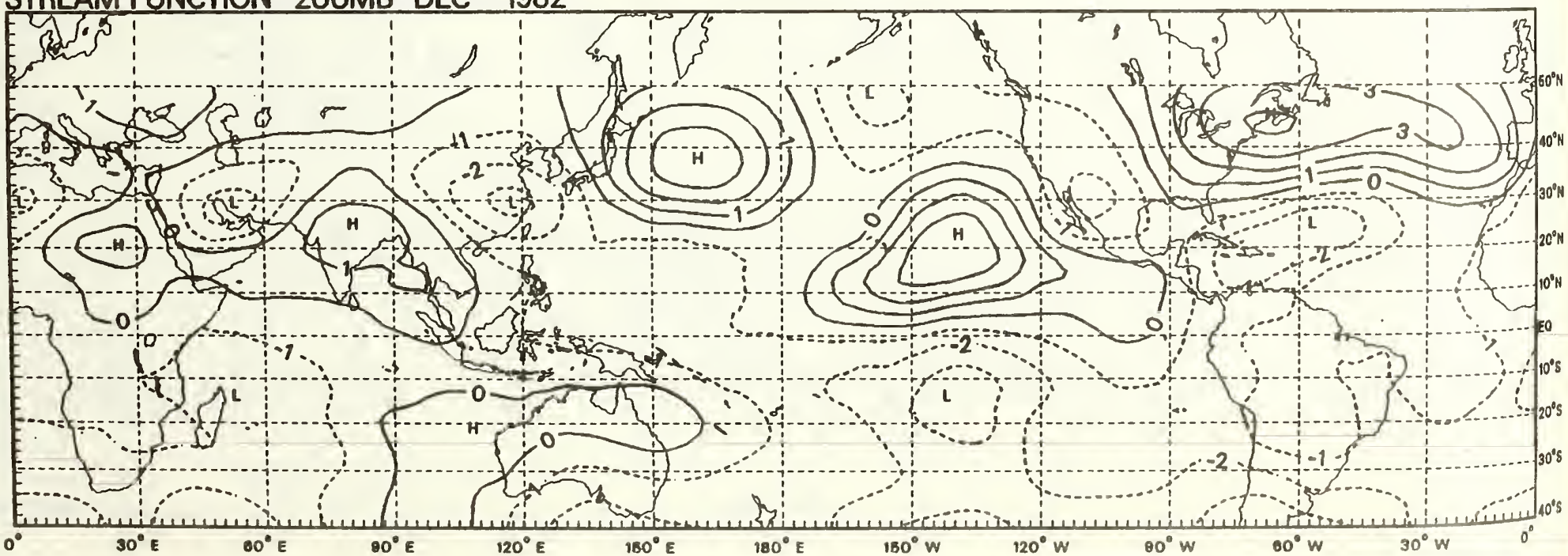

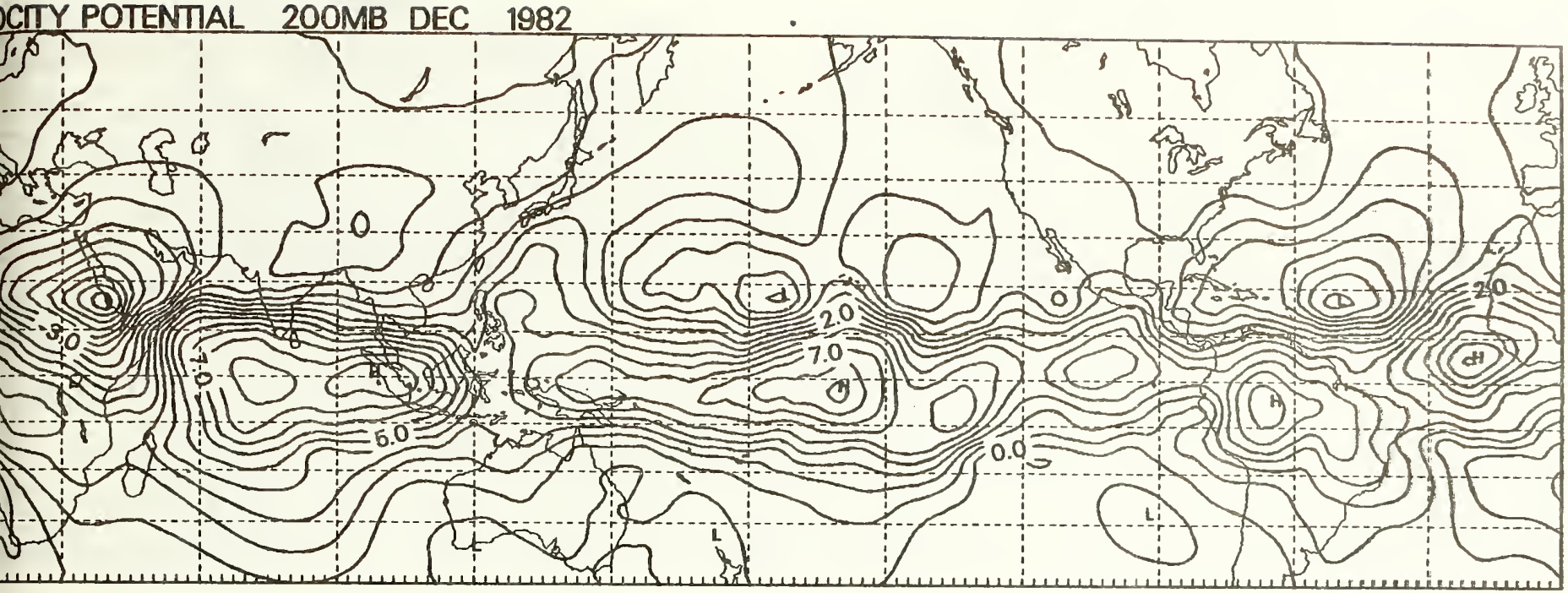
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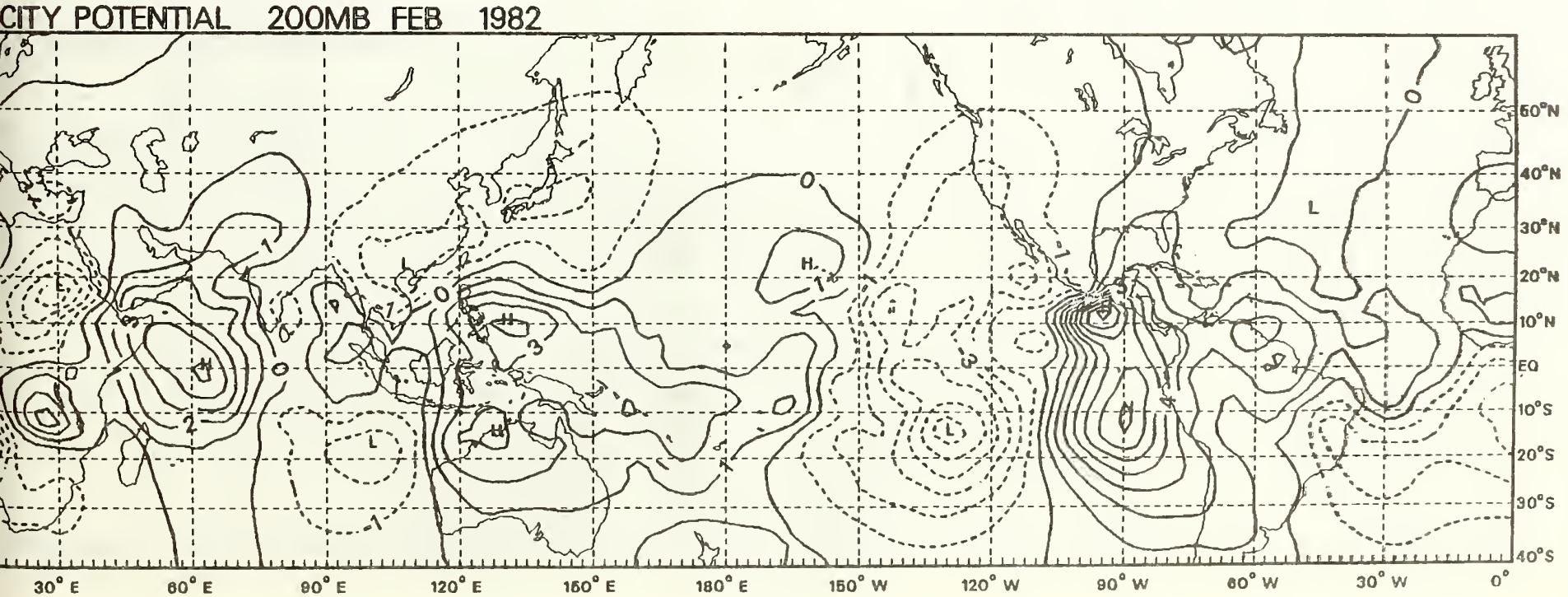
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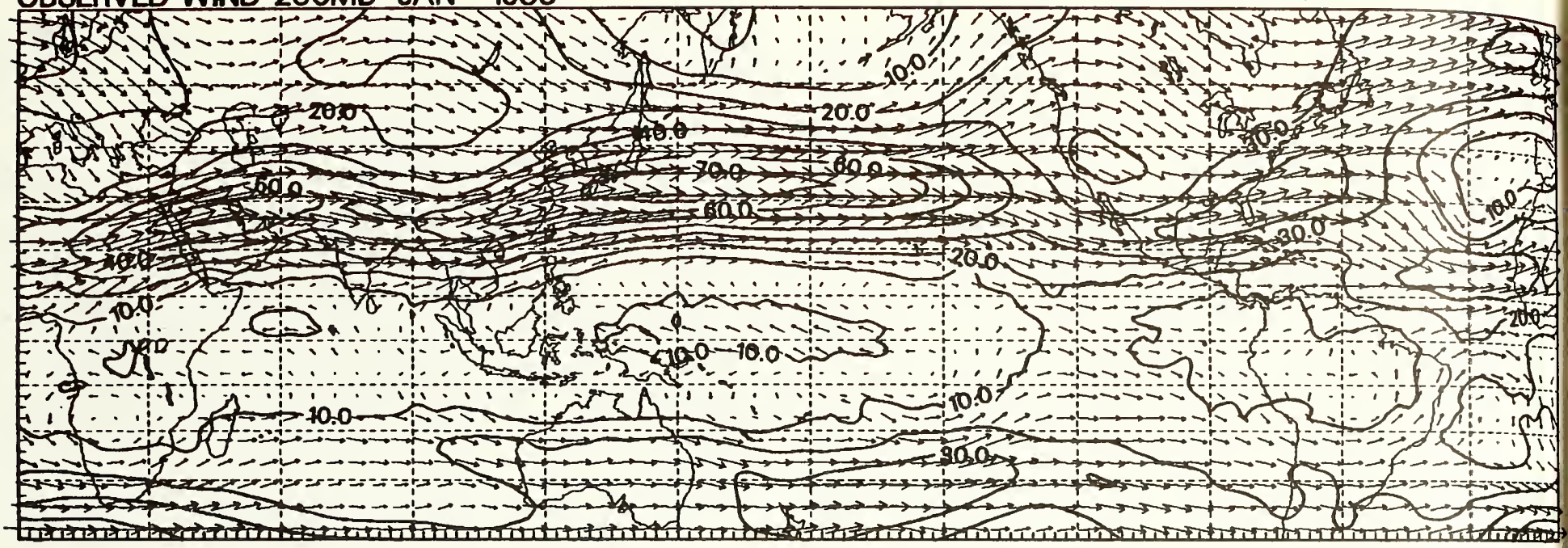

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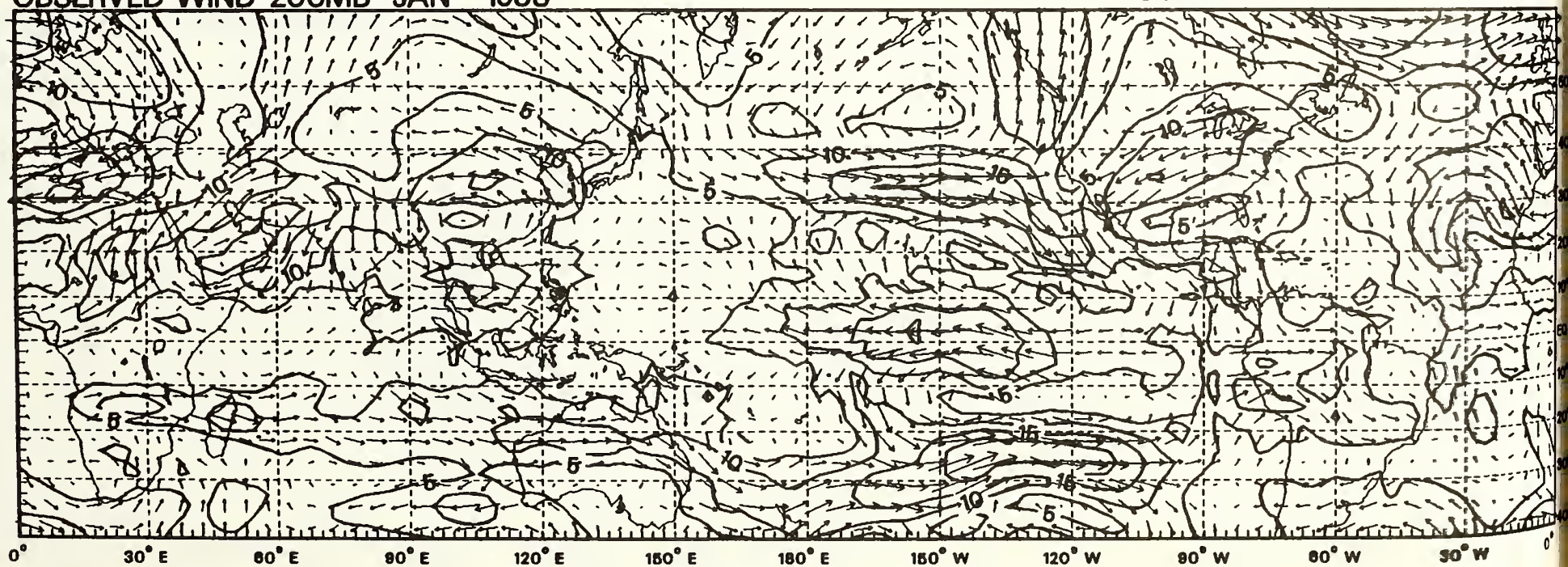

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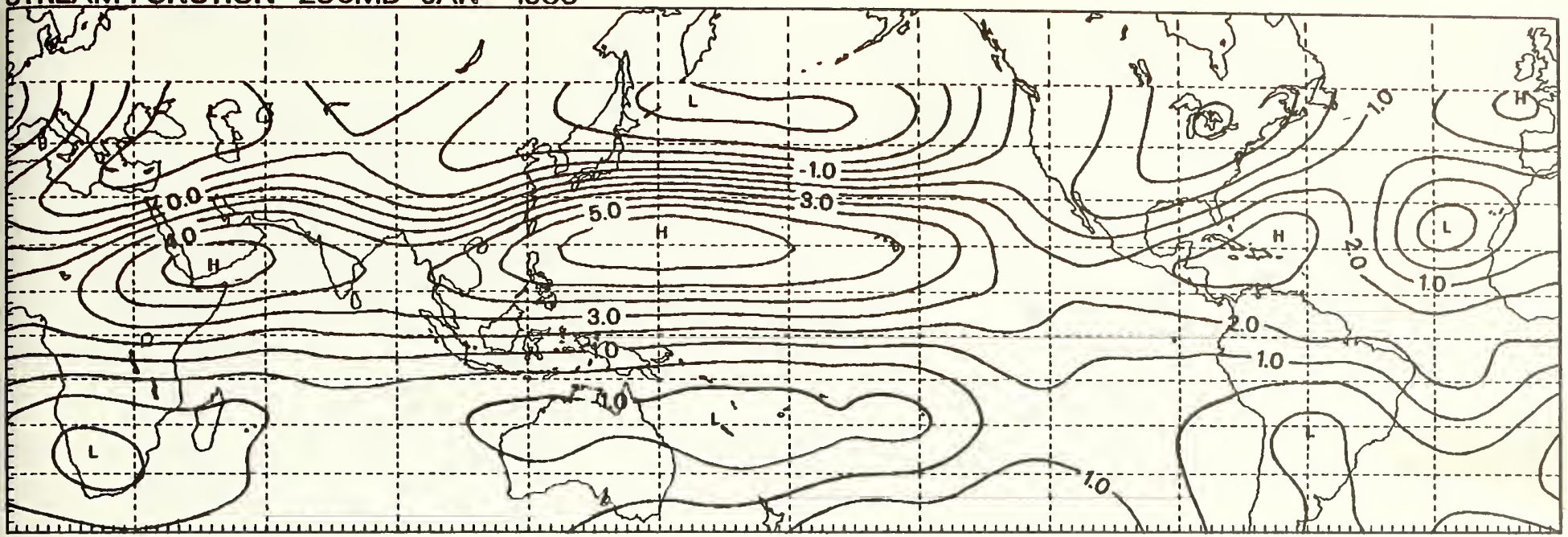

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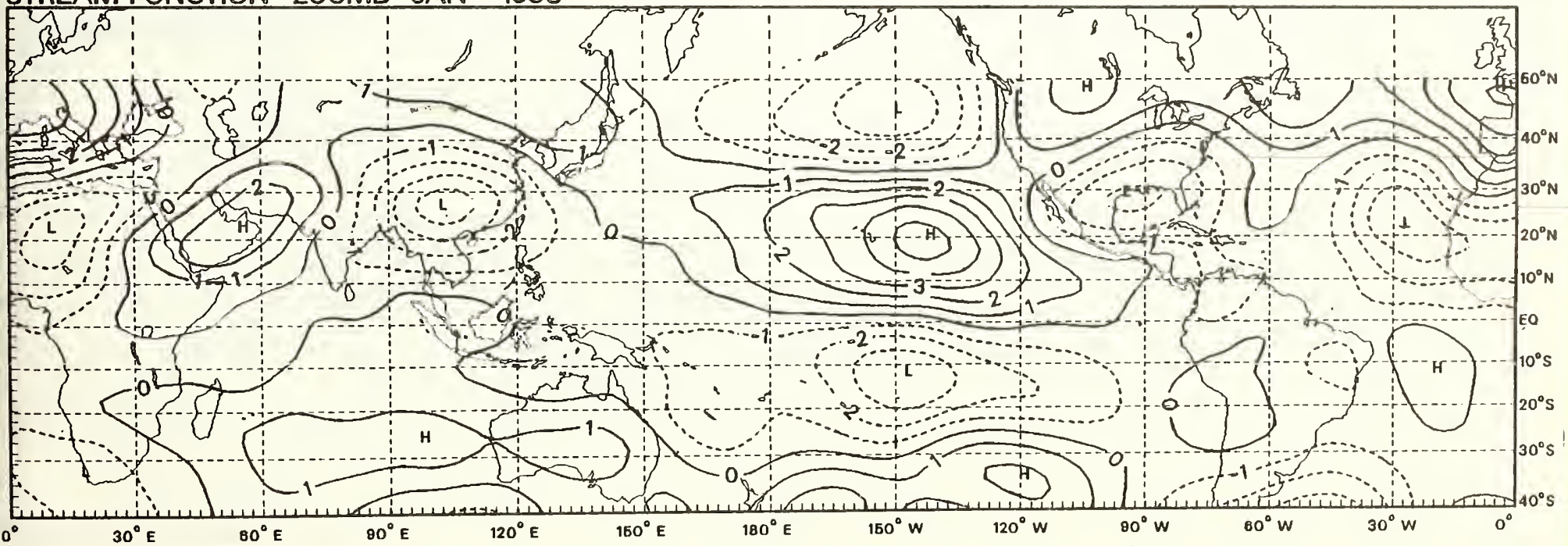

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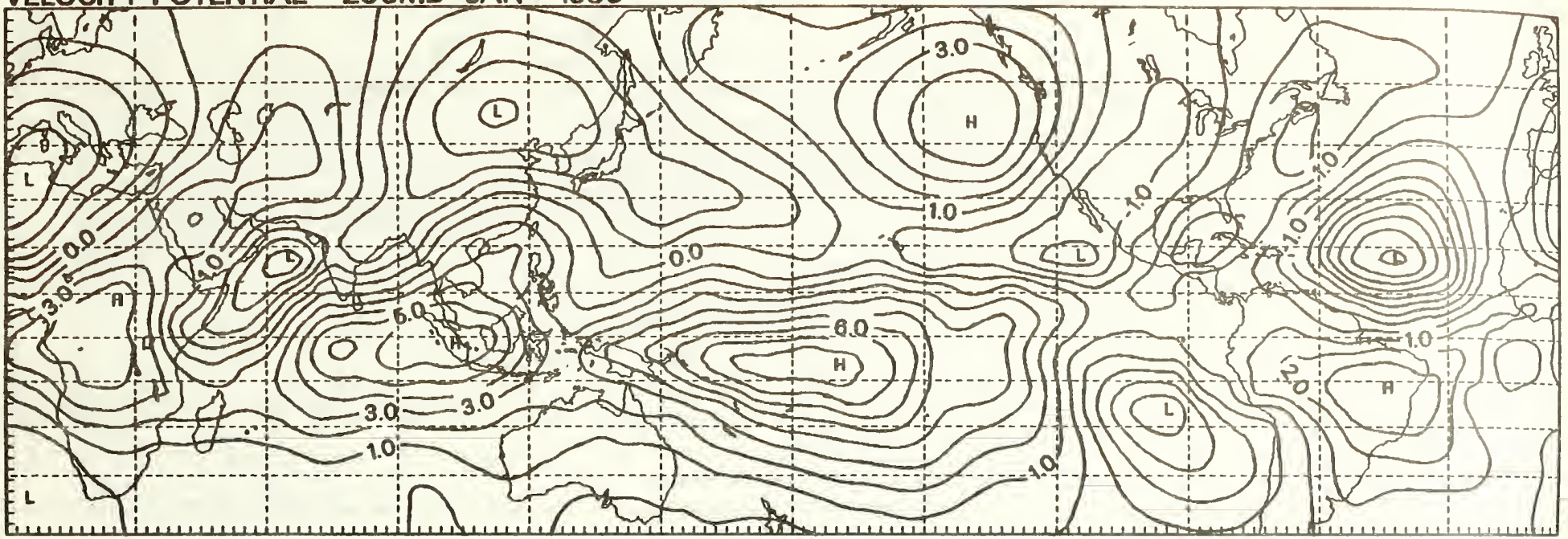

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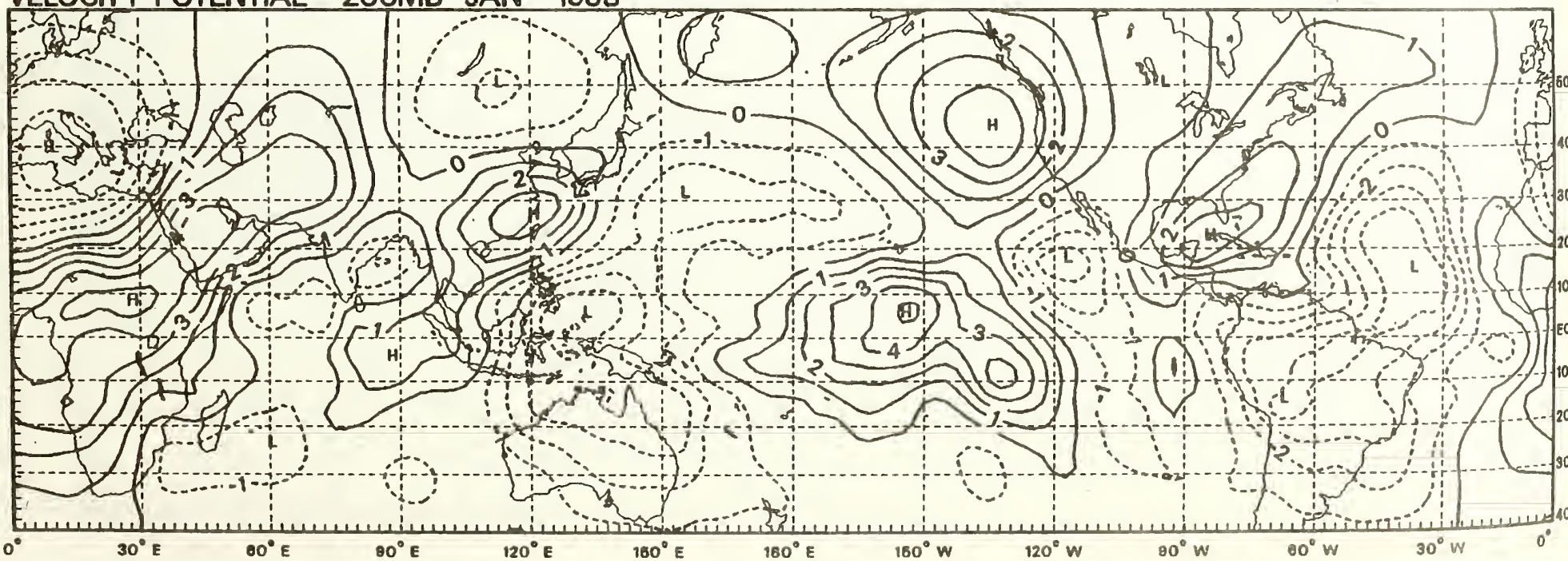

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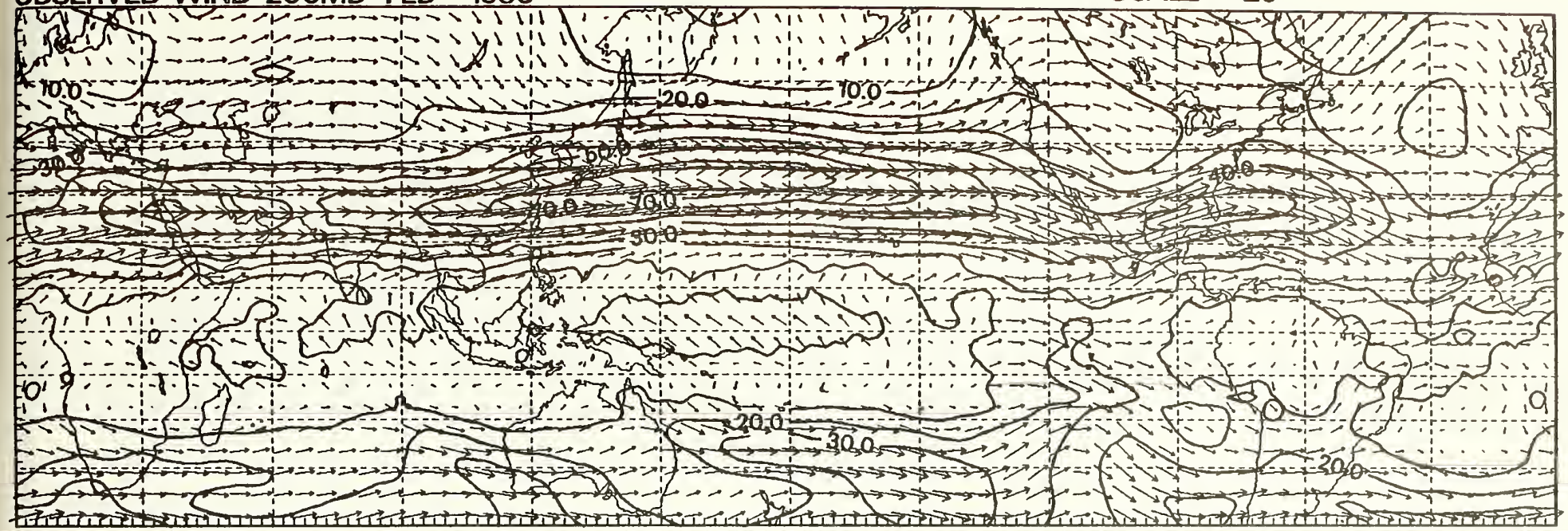

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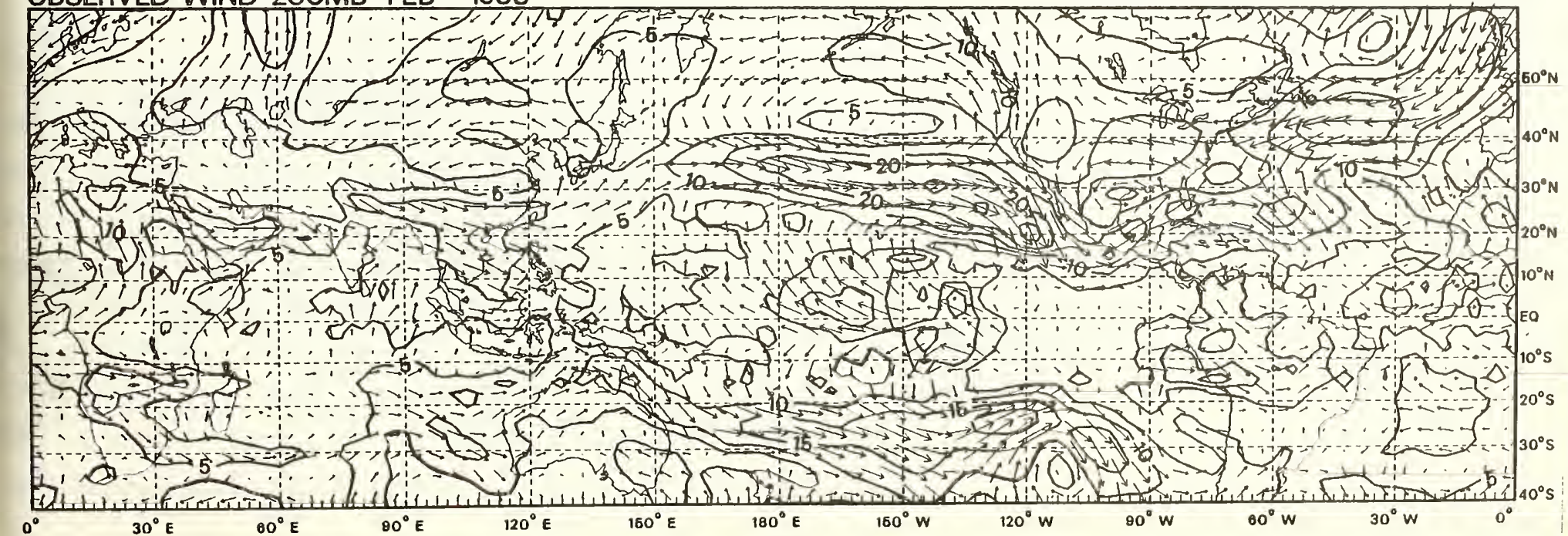

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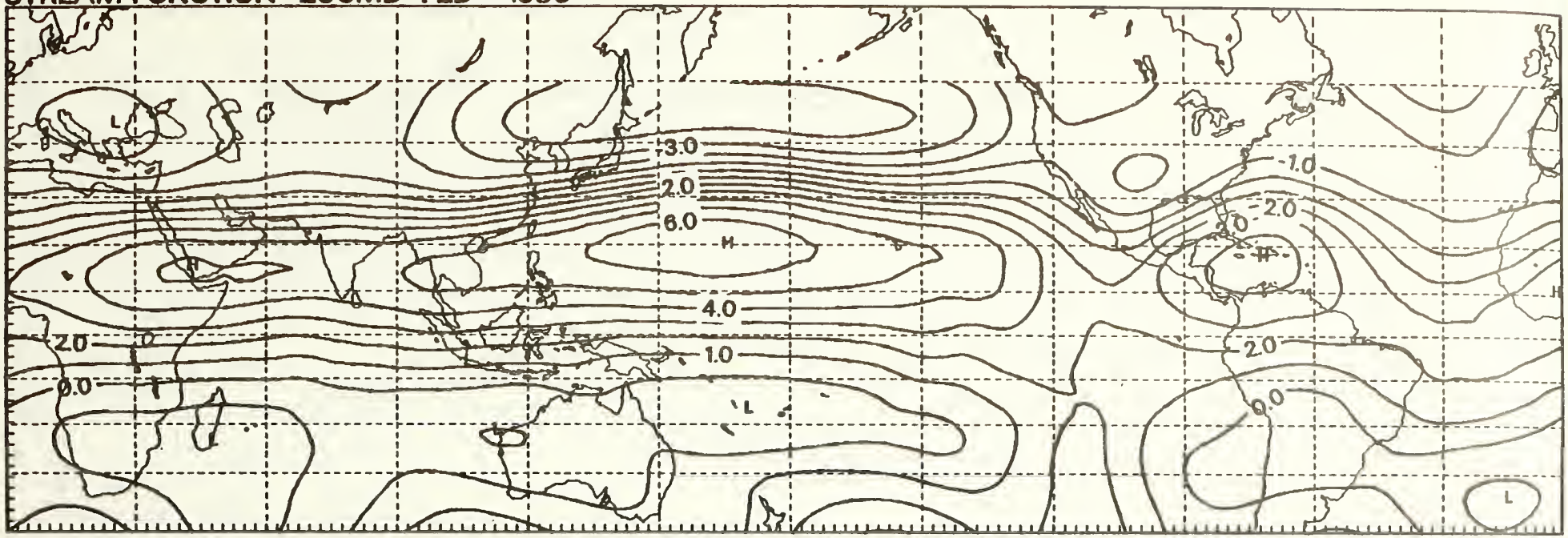

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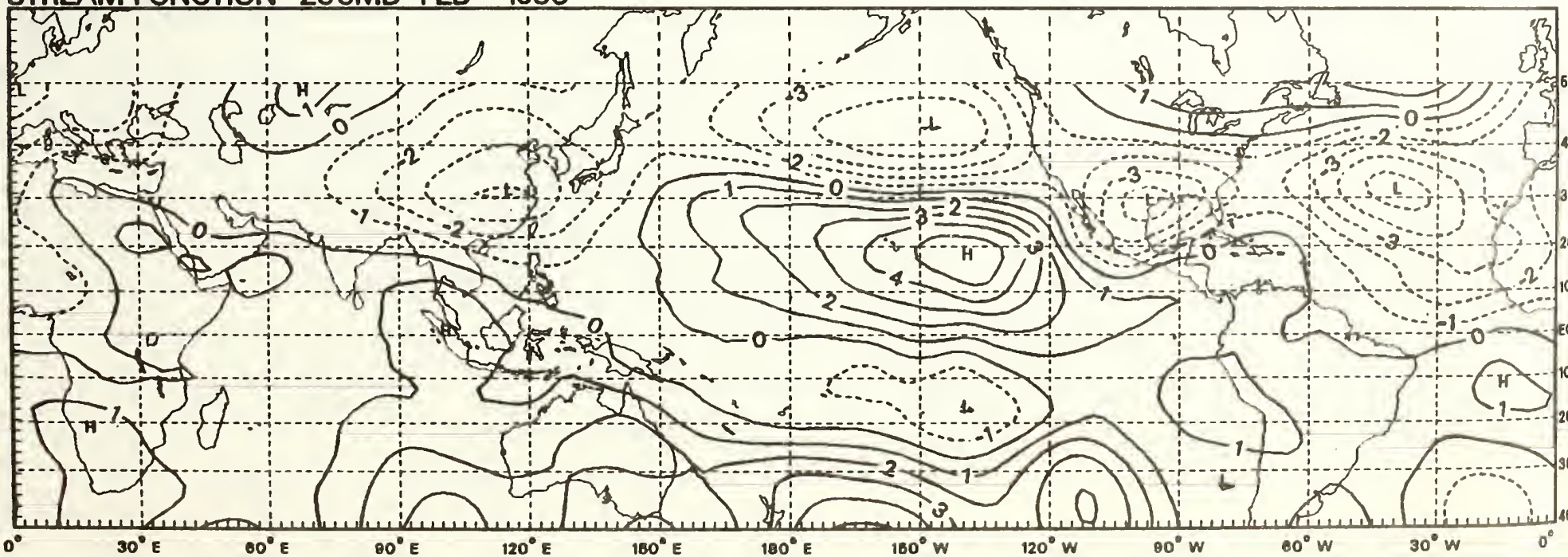

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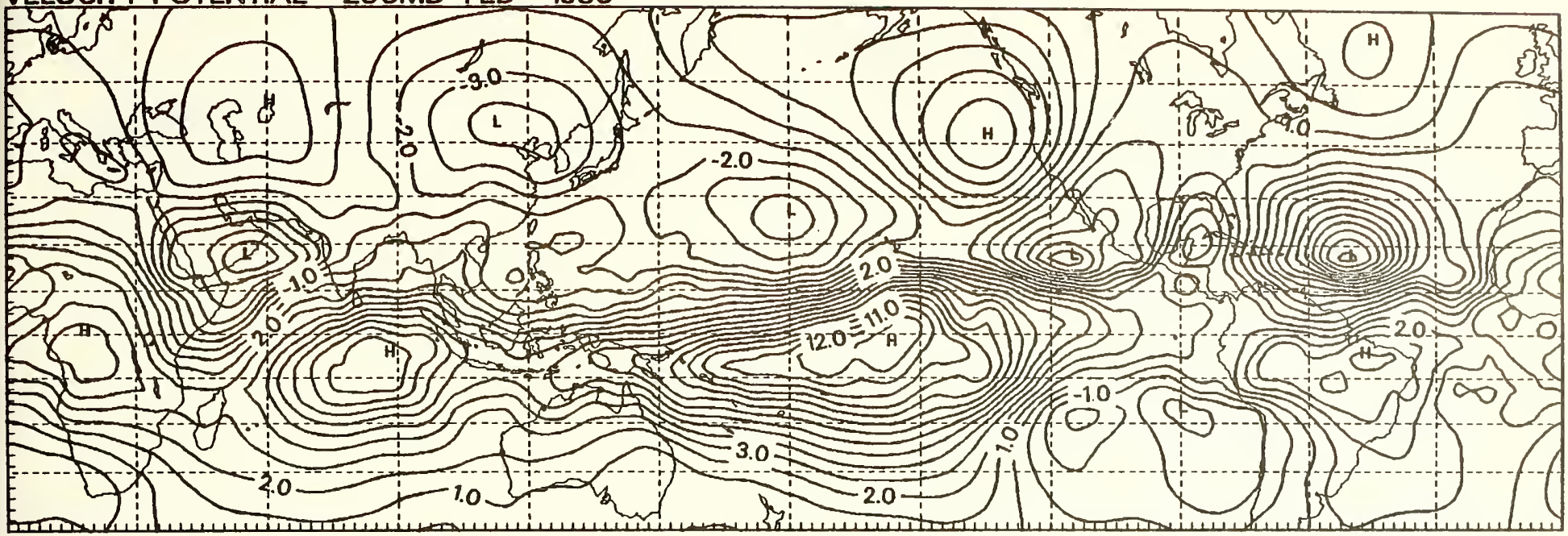

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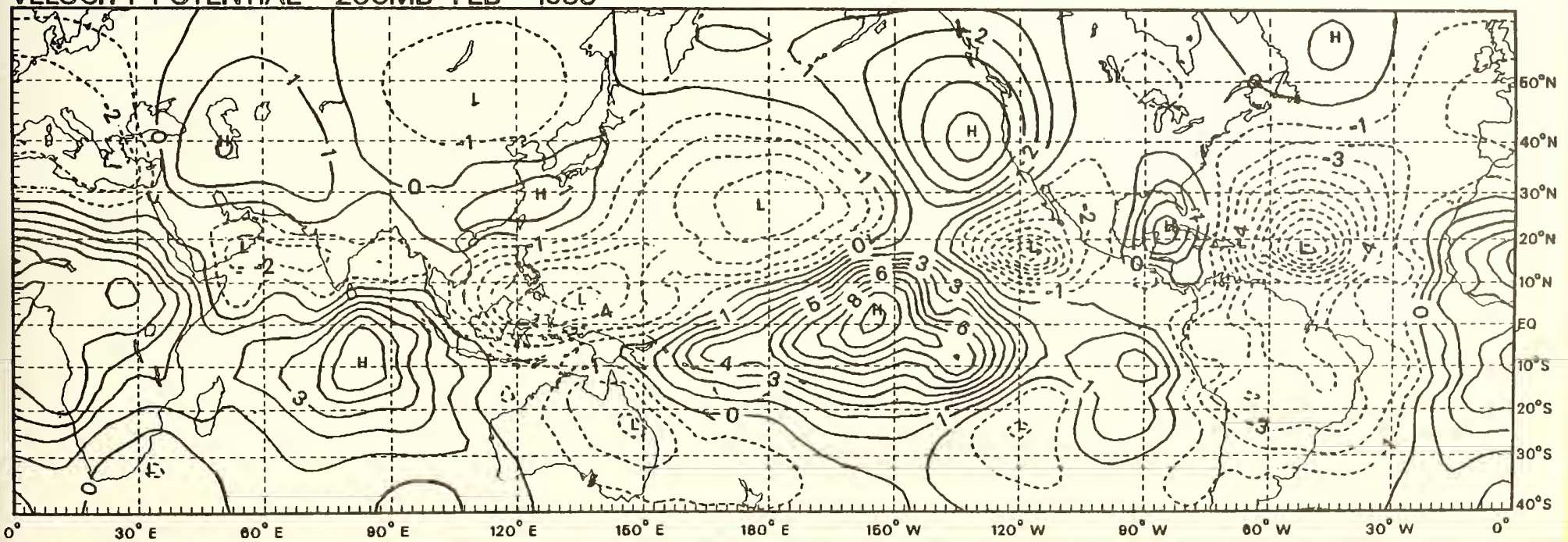

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